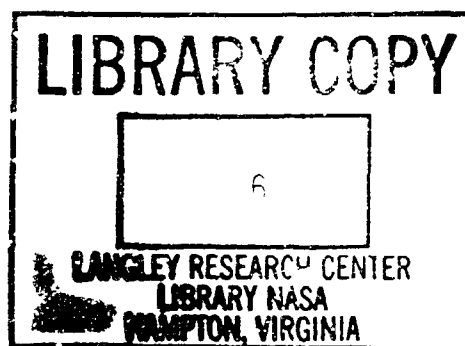


ASSURED CREW RETURN VEHICLE MAN-SYSTEMS INTEGRATION STANDARDS

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Prepared by:

Human Factors Engineering Department
Lockheed Engineering & Sciences Company
For National Aeronautics and Space Administration
July 1991

Approved by:

Laurie A. Weaver

Laurie Weaver, ACRV Crew Station Mgr.
Man-Systems Division
NASA-JSC

Clete R. Booher

9/24/92

Clete Booher, MSIS Manager
Man-Systems Division
NASA-JSC

Chris D. Perner

Chris Perner, Chief
Man-Systems Division
NASA-JSC

James P. Cioni 9-25-92

James Cioni, Deputy Manager
ACRV Project Office
NASA-JSC

Jerry Craig 9/25/92

Jerry Craig, Manager
ACRV Project Office
NASA-JSC

FOREWORD

This is Volume VI of the Man-Systems Integration Standards (MSIS) family of documents, which is contained in several volumes and a relational database. Each volume has a specific purpose, and each has been assembled from the data contained in the relational database.

The title and scope of the currently identified volumes are given below:

Volume I - Man-Systems Integration Standards

This document defines man-systems integration design considerations and requirements for development of manned space systems. This document is not limited to any specific NASA, military, or commercial program.

Volume II - Man-Systems Integration Standards - Appendices

This volume contains the appendices which pertain to Volumes I, III, and IV, and is organized as follows:

Appendix A	Bibliography
Appendix B	Paragraph References
Appendix C	Glossary
Appendix D	Abbreviations and Acronyms
Appendix E	Units of Measure and Conversion Factors
Appendix F	Unresolved Data Problems and Issues
Appendix G	Acceleration Regime Applicability
Appendix H	Videotape User's Guide
Appendix I	Standards Database Management System (SDMS) User's Guide
Appendix J	Keywords
Appendix K	MSIS Recipients Listing

Volume III - Man-Systems Integration Standards - Design Handbook

This document, when available, will contain figures, tables, and other pertinent data condensed from Volume I.

Volume IV - Space Station Freedom Man-Systems Integration Standards

This document serves as the Space Station Freedom program contractually binding man-systems integration design requirements. The data in this document is a subset of the data found in Volume I and defines the firm requirements which are pertinent to the Space Station Freedom program only.

Volume V - STS Man-Tended Payload Man-Systems Integration Standards

This volume documents all the man-systems integration design requirements for the development of man-tended payloads to be serviced by the Space Transportation System Orbiter Vehicle. The data in this document are a subset of the data found in Volume I and define the man-sys-

tems interfaces which are pertinent to man-tended payloads to be serviced by the STS in both shirt-sleeve and extravehicular orbital environments.

Volume VI - Assured Crew Return Vehicle Man-Systems Integration Standards

This document serves as the Assured Crew Return Vehicle project man-systems integration design requirements. The data in this document is a subset of the data found in Volume I and defines the requirements which are pertinent to the Assured Crew Return Vehicle as defined in the SPRD. Additional data and guidelines are provided to assist in the design.

MSIS Videotape - The videotape illustrates on-orbit human engineering problems encountered in Gemini, Apollo, Skylab, and Shuttle flights.

MSIS Relational Database - This database can be utilized to develop topical data paragraphs based on up to three key words, tailored lists of requirements, a list of references for any paragraph, a system-specific MSIS, and many other lists and documents.

Chapters of the MSIS family of documents are as follows:

1. Introduction
2. General Requirements
3. Anthropometry and Biomechanics
4. Human Performance Capabilities
5. Natural and Induced Environments
6. Crew Safety
7. Health Management
8. Architecture
9. Workstations
10. Activity Centers
11. Hardware and Equipment
12. Maintainability
13. Facility Management
14. Extravehicular Activity

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1.0 INTRODUCTION

1.1 PURPOSE

This document provides specific information to be used to ensure proper integration of the man-systems interface requirements and guidelines with those of other aerospace disciplines. This document is intended for use by design engineers, systems engineers, maintainability engineers, operations analysts, human factors specialists, and others who are engaged in the definition, development, and integration of equipment to support the Assured Crew Return Vehicle.

Only concise design requirements and guidelines considered applicable to the Assured Crew Return Vehicle project are provided.

1.1.2 ACRV System Missions

The ACRV System is described below in terms of its missions in the following order of priority:

- a. Return of one disabled crewmember of Space Station Freedom during reasonable medical emergencies.
- b. Return of Space Station Freedom crew from reasonable accidents or from reasonable failures of SSF systems.
- c. Return of Space Station Freedom crew during interruption of Space Shuttle launches.

1.2 SCOPE

This document establishes performance, design, development, and integration requirements for man-systems interfaces.

1.3 PRECEDENCE

Documents referenced herein shall form a part of this standard to the extent specified. In the event of apparent conflict between this standard and any referenced document, this standard shall take precedence. In the event of a conflict between this document and the ACRV System Performance Requirements Document (SPRD) JSC 34000 the ACRV SPRD will take precedence.

1.4 HOW TO USE THE DOCUMENTS

This document was extracted from the MSIS (Man-Systems Integration Standards, NASA-STD-3000 (MSIS)) relational data base in order to provide a man-systems requirements and guidelines document to the Assured Crew Return Vehicle (ACRV) project. In order to maintain continuity in section and figure numbering throughout the MSIS family of documents, paragraphs in the MSIS Volume I which are not considered directly applicable to this ACRV unique Volume VI are listed but indicated as not applicable in the body of this volume. This document contains a mix of design requirements and guidelines to be considered by the design engineers for incorporation into their segment, element or design specifications. In cases where a requirement is directly applicable to the ACRV, it will be stated in the ACRV SPRD JSC 34000. It is recommended that those designing hardware and systems for ACRV acquire a copy of Volume I of the MSIS because the considerations

and examples sections of each of the chapters in that volume contain background and supporting information which could be of considerable value in this design process.

1.5 HOW TO USE THE STANDARDS RELATIONAL DATABASE - N/A

1.6 DEFINITIONS AND ABBREVIATIONS

A set of basic definitions is herewith established for orientation and simplification of organization and coordination of work. The definitions are followed by a set of updated names, agreed-to abbreviations, and corresponding comments.

1.6.1 Human Factors/Ergonomics

The terms Human Factors and Ergonomics are often used interchangeably. Both are concerned with the interaction of the operator and the task demands. However, they have somewhat different focuses. Human Factors relates to the evaluation of all aspects of the capabilities and limitations of the human as these relate to the integration of man into the total man/machine systems complex. The principal goal is the enhancement of functional effectivity while maintaining or increasing human well-being (e.g. physical and mental health, productivity, safety, and satisfaction). Ergonomics focuses on the measurement of the impact of systems design and integration on the work output of the operator, with the goal of obtaining the maximum productivity with minimum fatigue. These evaluations must include the users physiologic responses to physically and mentally demanding tasks in an environment of other stressors such as heat, noise, and vibration.

1.6.2 Human Engineering

Human Engineering (or Human Factors Engineering) is the systematic application of relevant data, principles, and practices of Human Factors and Ergonomics to the design of equipment, operations, and systems. These data, principles, and practices come from a number of fields of study, including:

- a. All anatomical and physiological systems with emphasis on sense organs and skeletal musculature,
- b. Anthropometry,
- c. Kinematics and dynamics of body motion,
- d. Physical work performance,
- e. Environmental stresses,
- f. Psychology,
- g. Sensory and perceptual behavior,
- h. Learning and training,

i. Motivation, and

j. Sociology.

1.6.3 Man-Systems Integration

Man-Systems Integration applies the systems' approach to the integration of the user and the "machine" to form an effective, symbiotic Man-Machine System. Hardware, software, and operations development must take into account the limitations and capabilities of the human operator. Selection and training of personnel impacts all facets of Man-Systems Integration.

1.6.4 Man-Machine Systems

A Man-Machine System is a combination of one or more human beings and one or more physical systems that are integrated for the common purpose of performing a specific task. In this concept, the human is considered a component or subsystem of the larger system. These components interact within the system environment to bring about, from given inputs, some desired output. The major elements of a system that must be addressed during system development are hardware and software, personnel, operating procedures, and technical data.

1.6.5 Man-Machine Interface (MMI)

The MMI is the interface through which the human is able to sense the state of the system and environment and respond accordingly. This includes hardware, its spatial interrelationships, and the display of information. The latter includes the modality, quantity, quality, arrangement, and organization of the information presentation.

1.6.6 Human-Computer Interface (HCI)

The HCI is the communication interface between the user and the computer. Since data and information is transmitted and received via this interface, it is considered a matter of dialogue management. This is a software interface. To facilitate the real-time interactions between the user and computer, the HCI employs a variety of tools, including methods for moving between displays, windowing techniques, methods for selecting information from a display, user guidance, and interactive dialogue techniques.

1.6.7 Interface Language

Through the use of the interface language, the operator conveys commands or queries to the computer and the computer conveys information to the user. Linguistic styles involve the use of menus, windows, forms, etc.

1.6.8 Habitability

Habitability may be defined as those provisions of the facility designed to provide an environment which enhances crew comfort, mental well-being, productivity, and safety. The basic level of habitability deals with the immediate environment, including climate, food, noise, light, etc., that influence the human psychophysiological response.

The extended level of habitability is introduced to take care of the long-term condition of the on-orbit stay time and shall support not only the individuals' physical health but also the mental/psychological health because experience has shown that with the passage of time deleterious effects of isolation and confinement gain prominence.

1.6.9 Anthropometry

Anthropometry is the study of body dimensions. Anthropometric data falls into two categories:

- a. Static anthropometry, which deals with simple dimensions of the stationary human; e.g., weight, stature, and the lengths, breadths, depths, and circumferences of the human body.
- b. Dynamic anthropometry, which deals with the body dimensions during motion; e.g., reach and angular ranges of various joints.

1.6.10 Biomechanics

Biomechanics is the application of the principals and techniques of mechanics to define the capabilities, functions, and structure of living organisms (humans). Ergonomic applications deal with the mechanisms, range, and accuracy of human movement, as well as strength (force), speed, and endurance of the human body.

1.6.11 Physiology

Physiology is the study of the function and vital processes of the total organism, including how the body performs.

The study of ergonomics provides information on how work and exposure to the working environment affect the normal working of the body. This is accomplished through the measurement of the costs (energy, time, fatigue) of human adjustment to work, as this is influenced by the environment and/or the modification of working conditions, to enhance the efficiency of the worker. The goal of ergonomics is to reduce fatigue, physical stress, increase comfort, and reduce monotony or boredom.

1.6.12 Psychology

Psychology is the study of the functioning of the mind and mental operations, especially as they are shown to affect human behavior. Particular emphasis is placed on psychomotor skills (acquired abilities to perform tasks with the muscles in response to sensory stimuli, involving learning and feedback), perception, mental abilities, and mental workload.

1.6.13 Sociology

Sociology is a study of those factors which deal with human interfaces and the impact on group and interpersonal behavior. Some of these factors, which impact group dynamics, include educational ethnic origins, background, cultural mores, religion, and authority interfaces.

1.6.14 Occupational Health (Industrial Medicine)

Occupational health (industrial medicine) deals with the physical and mental health effects of a person's job and the working environment.

1.6.15 Environment

The environment includes all external factors that affect the human being, such as

- a. Climate.
- b. Vibro-acoustics.
- c. Lighting.
- d. Working/living space.
- e. Psycho-socio-cultural environment.
- f. Gravity (hyper, normal, hypo, micro)
- g. Radiation.
- h. Potentially hazardous factors, such as : Microorganisms, noxious/toxic compounds, and/or waste contamination (trash, body, etc.)

Many of these factors overlap or interact with each other.

2.0 GENERAL REQUIREMENTS

2.1 INTRODUCTION - N/A

2.2 GENERAL DESIGN CONSIDERATIONS - N/A

2.3 GENERAL DESIGN REQUIREMENTS - N/A

2.3.1 Simplicity Design Requirements

The design shall be as functionally simple as possible consistent with the functions desired and the expected service conditions.

2.3.2 Standardization Design Requirements

The ACRV man-machine interfaces shall be standardized to the following design requirements:

- a. Hardware Operation Standardization - The operation of crew-use equipment in the ACRV shall functionally perform in a manner similar to that of the Space Station Freedom (SSF) hardware.
- b. Computer Procedures Standardization - The operating procedures for the use of an ACRV computer shall be similar to that of SSF user/computer procedures.

3.0 ANTHROPOMETRY AND BIOMECHANICS

3.1 INTRODUCTION - N/A

3.2 GENERAL ANTHROPOMETRICS AND BIOMECHANICS RELATED DESIGN CONSIDERATIONS - N/A

3.3 ANTHROPOMETRICS AND BIOMECHANICS RELATED DESIGN DATA

3.3.1 Body Size

3.3.1.1 Introduction - N/A

3.3.1.2 Body Size Design Considerations - N/A

3.3.1.3 Body Size Data Design Requirements

The data in this section shall be used as appropriate to achieve effective integration of the crew and the Assured Crew Return Vehicle (ACRV).

Dimensions of the projected year 2000, 40 year old American male and the 40 year old Japanese female are given in Figure 3.3.1.3-1. These dimensions apply to a specific posture in 1-g conditions only. Dimensions expected to change significantly due to weightlessness are marked. Notations regarding these dimensions are at the end of the Figure.

3.3.2 Joint Motion

3.3.2.1 Introduction - N/A

3.3.2.2 Joint Motion Design Considerations - N/A

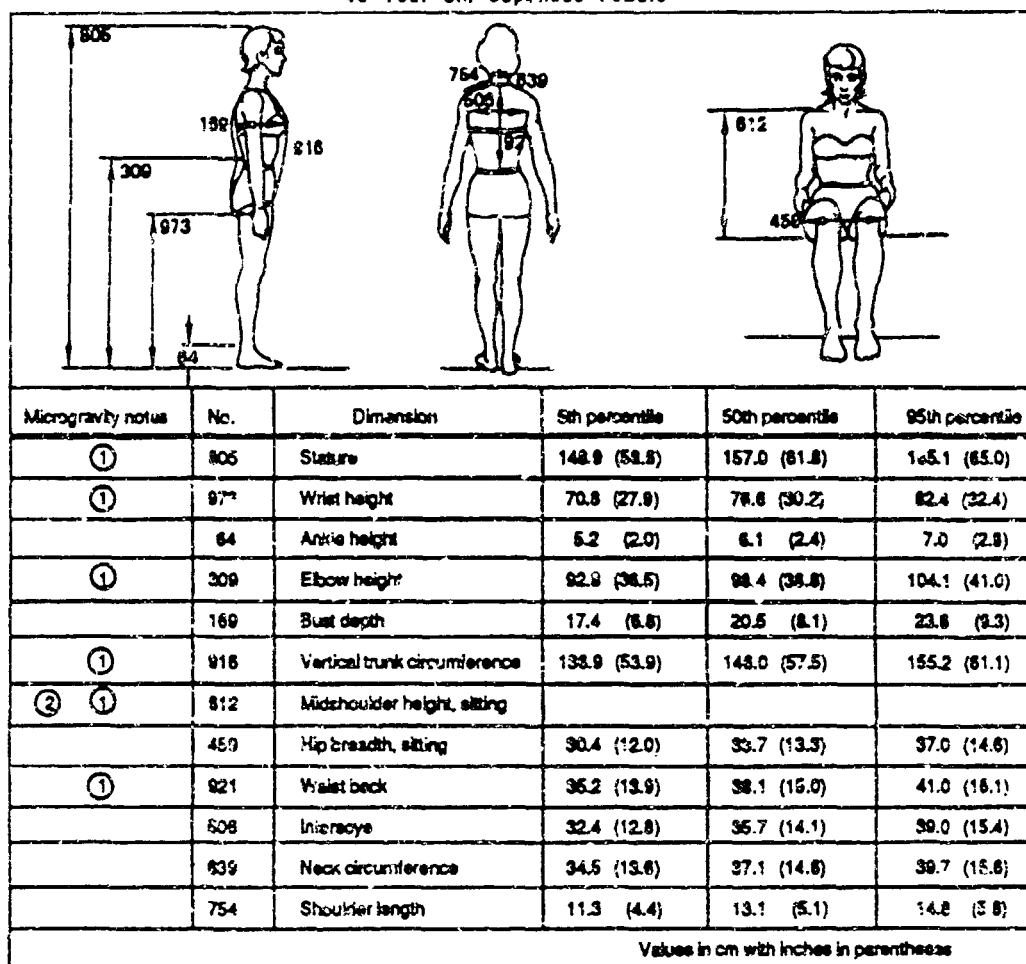
3.3.2.3 Joint Motion Data Design Requirements

The data in this section shall be used as appropriate to achieve effective integration of the crew and the Assured Crew Return Vehicle (ACRV).

3.3.2.3.1 Joint Motion Data, Single Joint Design Requirements

Figure 3.3.2.3.1-1 shows single joint movement ranges for both males and females.

40-Year-Old Japanese Female



Notes

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

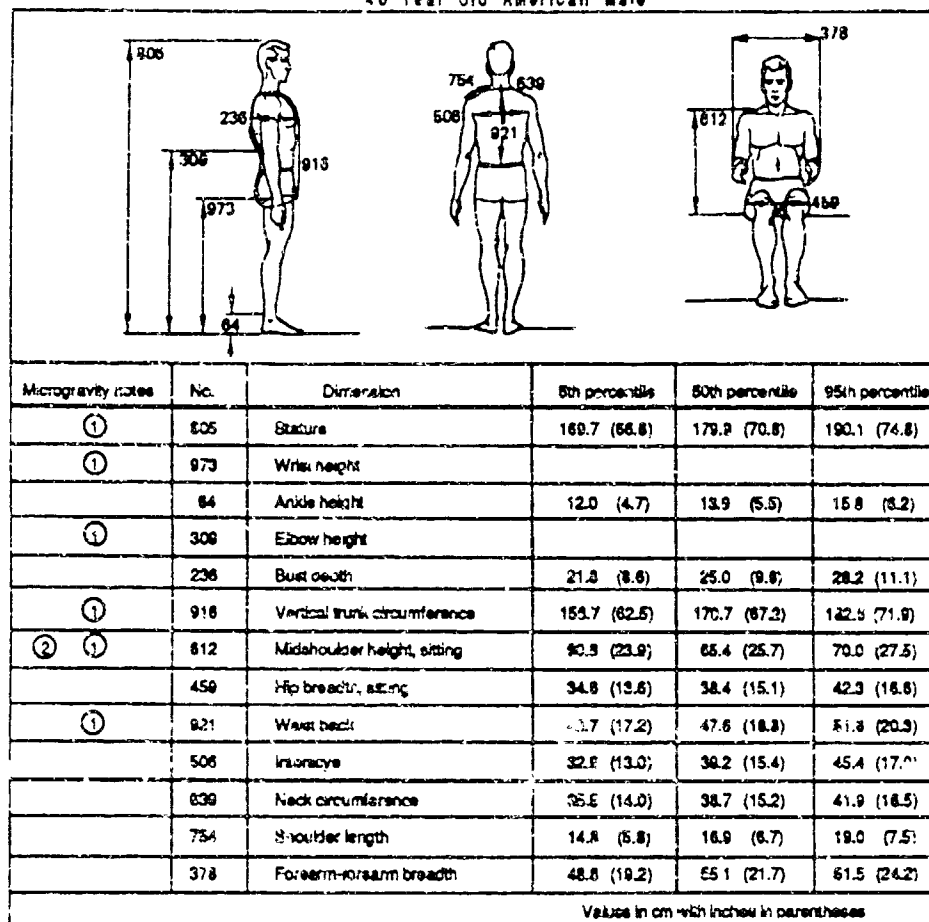
- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmembers were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief of pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (continued)

40-Year-Old American Male

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Notes

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmember were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief of pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches)).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.

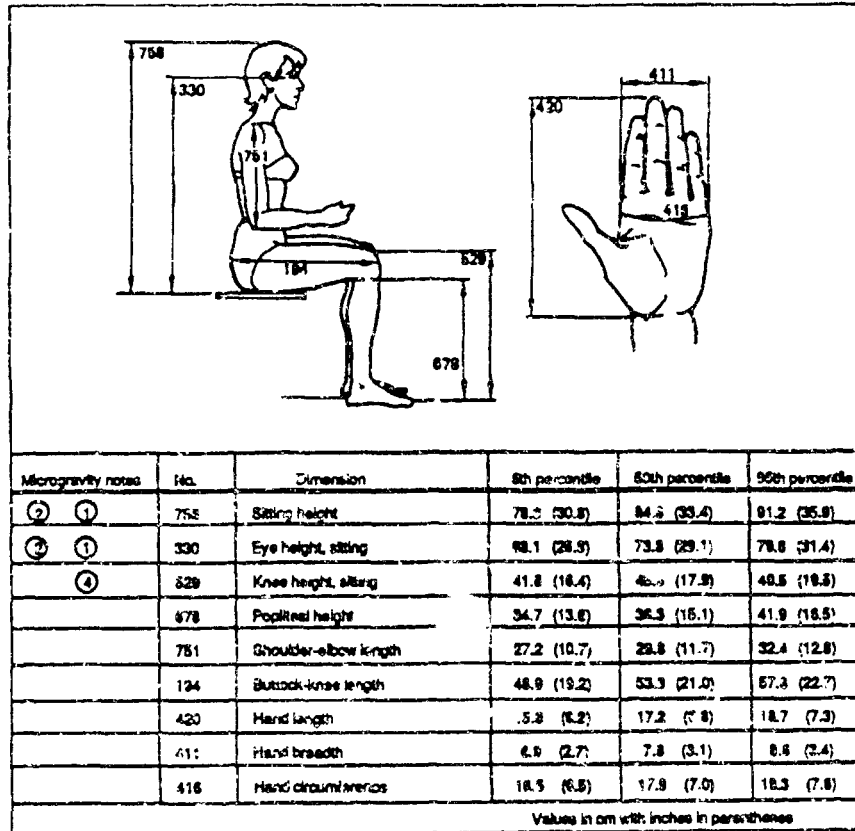
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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2006 in One Gravity Conditions (continued)

40-Year-Old Japanese Female



Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

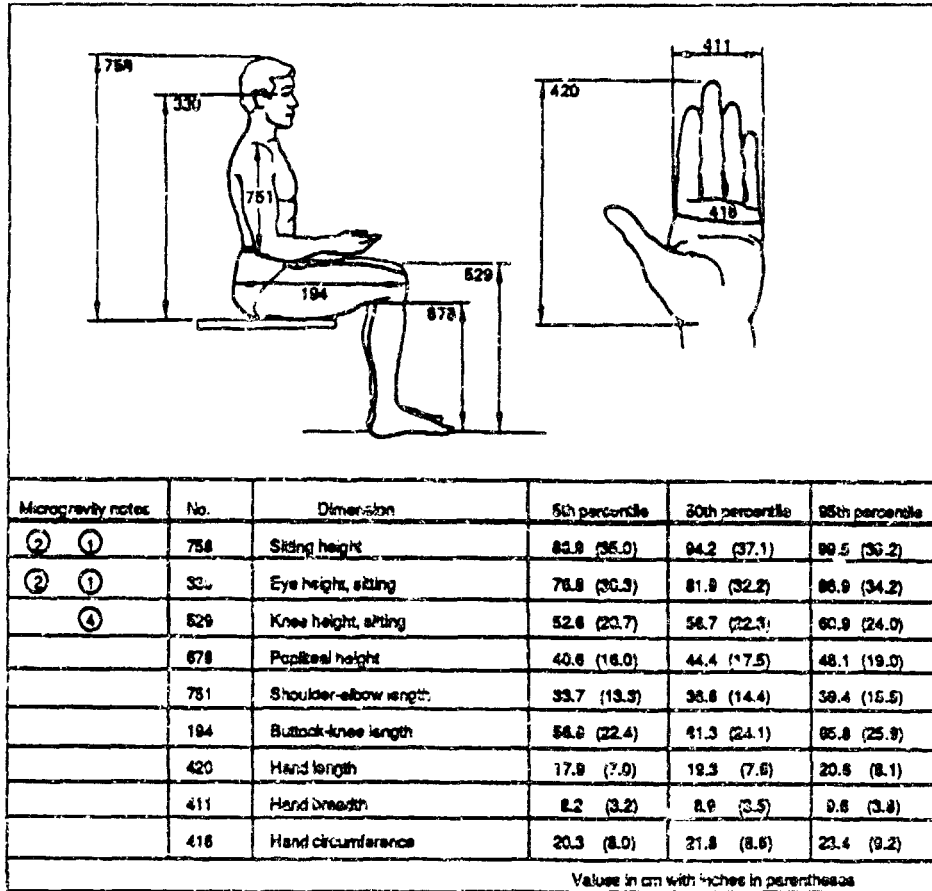
B) Application of dimensions to microgravity conditions:

- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmember were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief or pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches)).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.
- ③ Knee height - sitting may increase slightly in microgravity due to relief of the pressure on the heel which it occurs when it measured on the ground. The increase is probably not more than 2 to 3 mm (0.1 inch).

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old American Male



Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

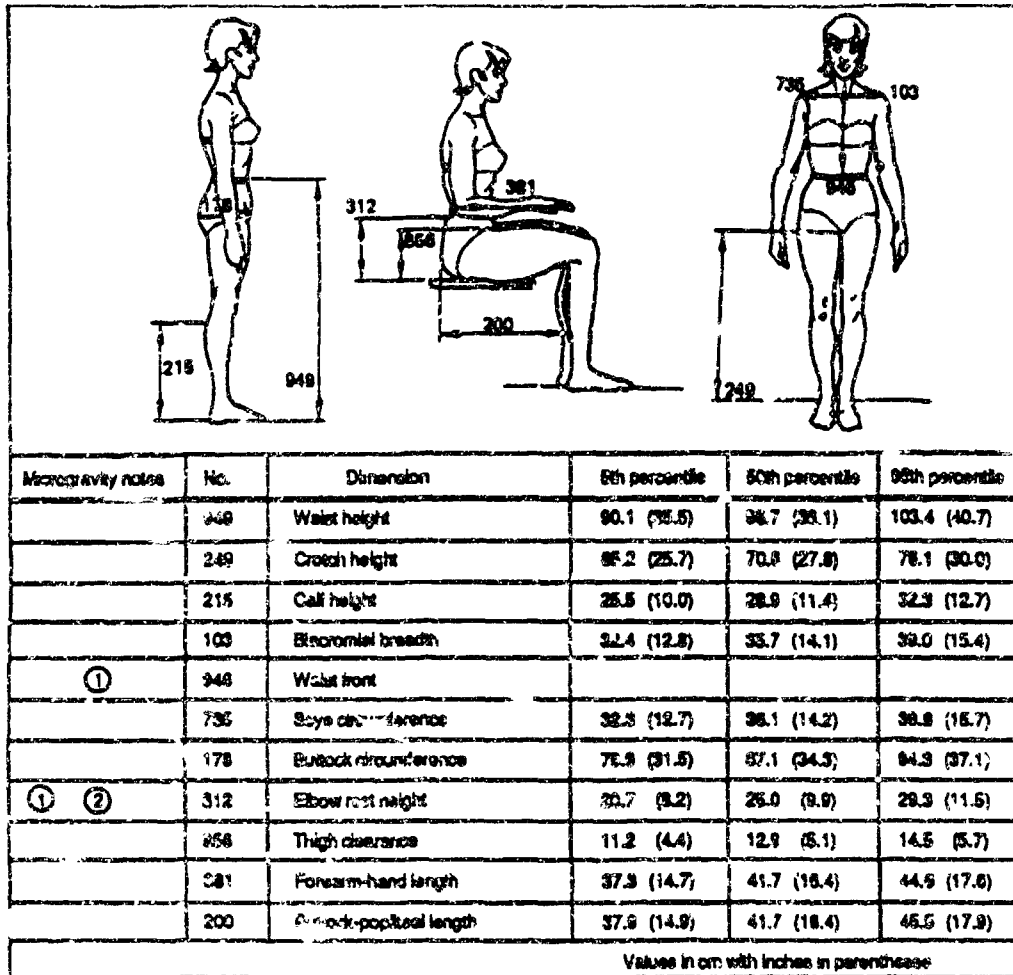
B) Application of dimensions to microgravity conditions:

- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmember were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief of pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches)).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.
- ④ Knee height - sitting may increase slightly in microgravity due to relief of the pressure on the heel which it occurs when it measured on the ground. The increase is probably not more than 2 to 3 mm (0.1 inch).

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old Japanese Female



Notes

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmember were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief of pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches)).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.

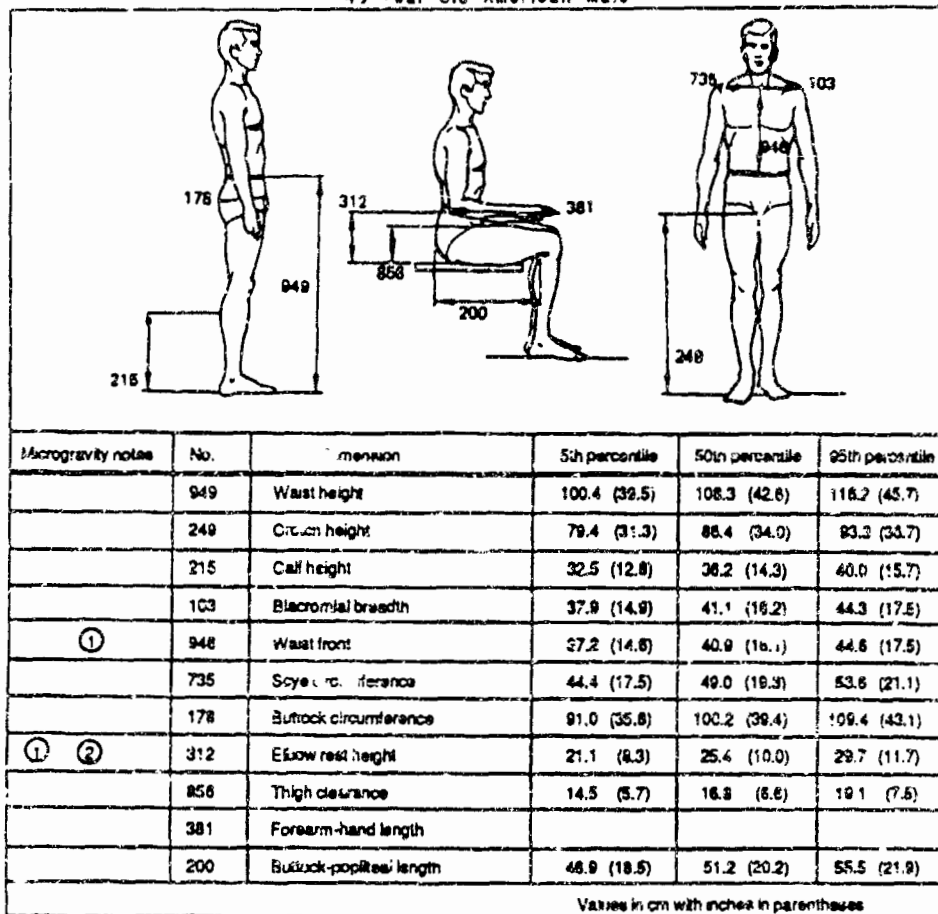
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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (continued)

49-Year-Old American Male



Notes

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ② Sitting height would be better named as buttock-vertex in microgravity conditions, unless the crewmember were measured with a firm pressure on shoulders pressing him or her against a fixed, flat "sitting" support surface. All sitting dimensions (vertex, eye, shoulder, and elbow) increase in weightlessness by two changes:
 - a) Relief of pressure on the buttock surfaces (estimated increase of 1.3 to 2.0 cm (0.5 to 0.8 inches)).
 - b) Extension of the spinal column as explained in note 1 above 3% of stature on ground.

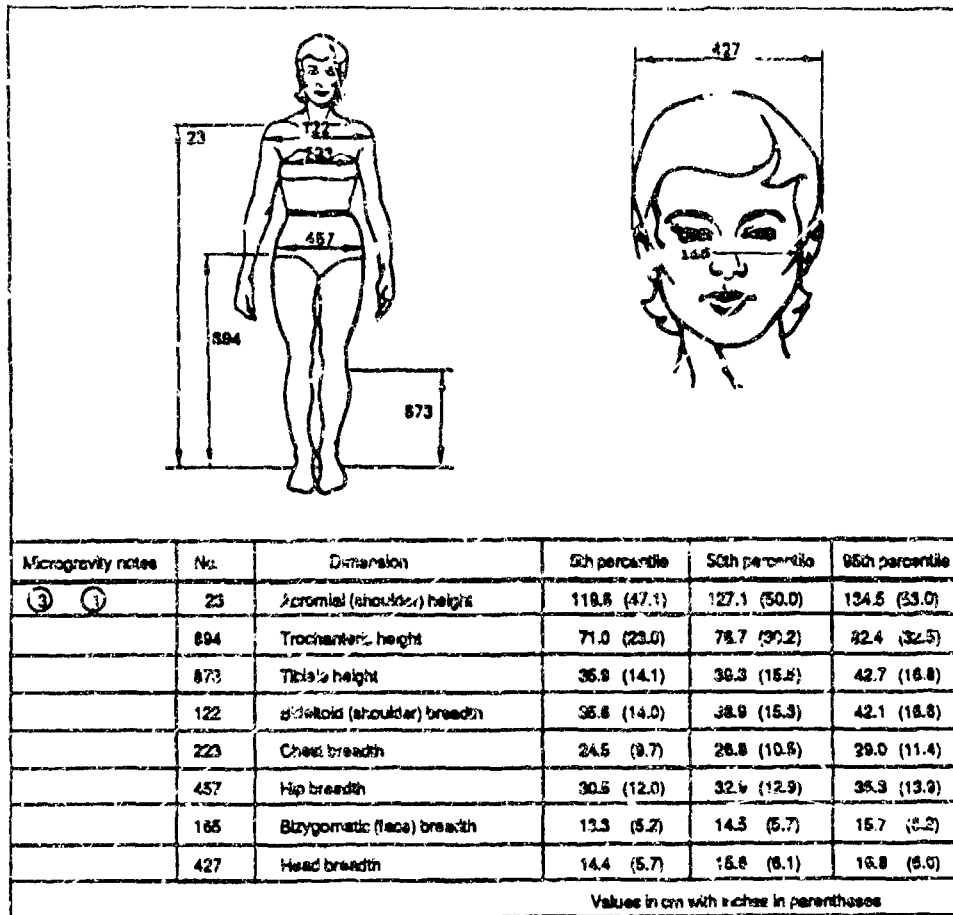
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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (continued)

40-Year-Old Japanese Female



Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

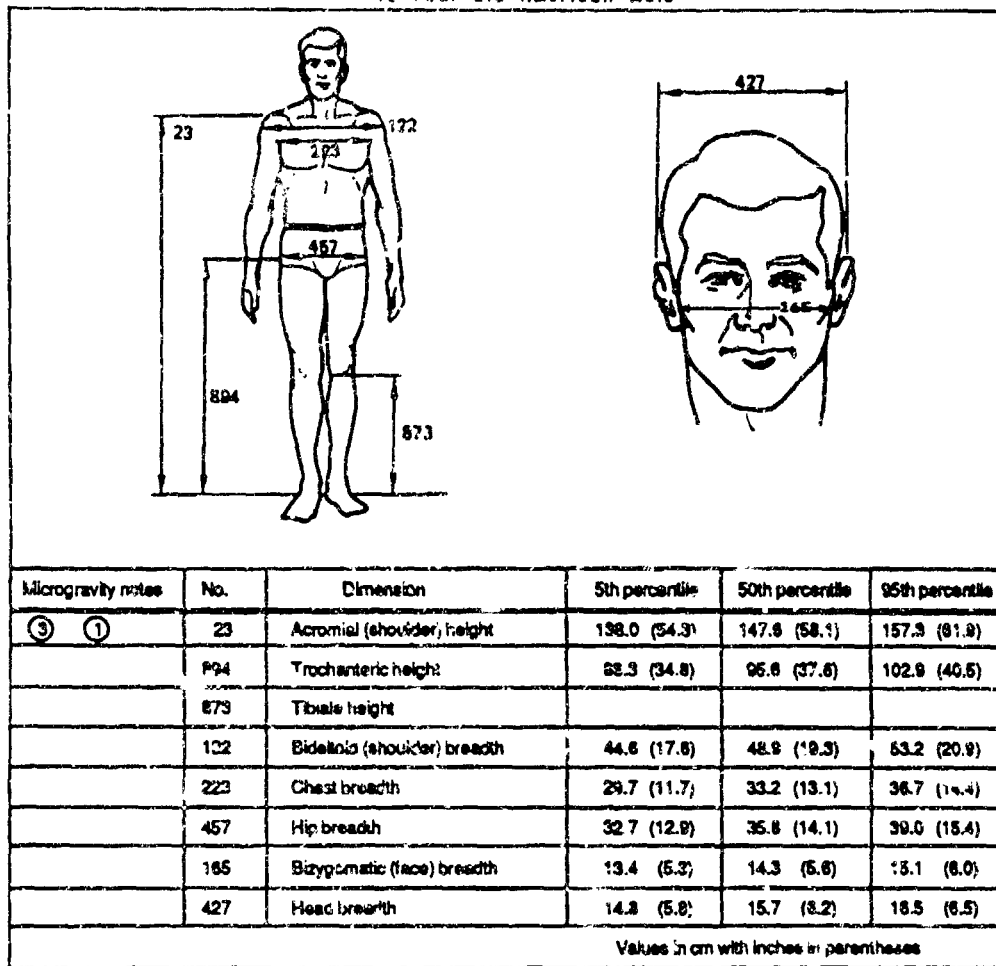
- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects (increases) other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ③ Shoulder or acromial height, sitting or standing, increases during weightlessness due to two factors:
 - a) Removal of the gravitational pull on the arms.
 - b) Extension of the spinal column as explained in note 1 above (3% of stature on ground).

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old American Male

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Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

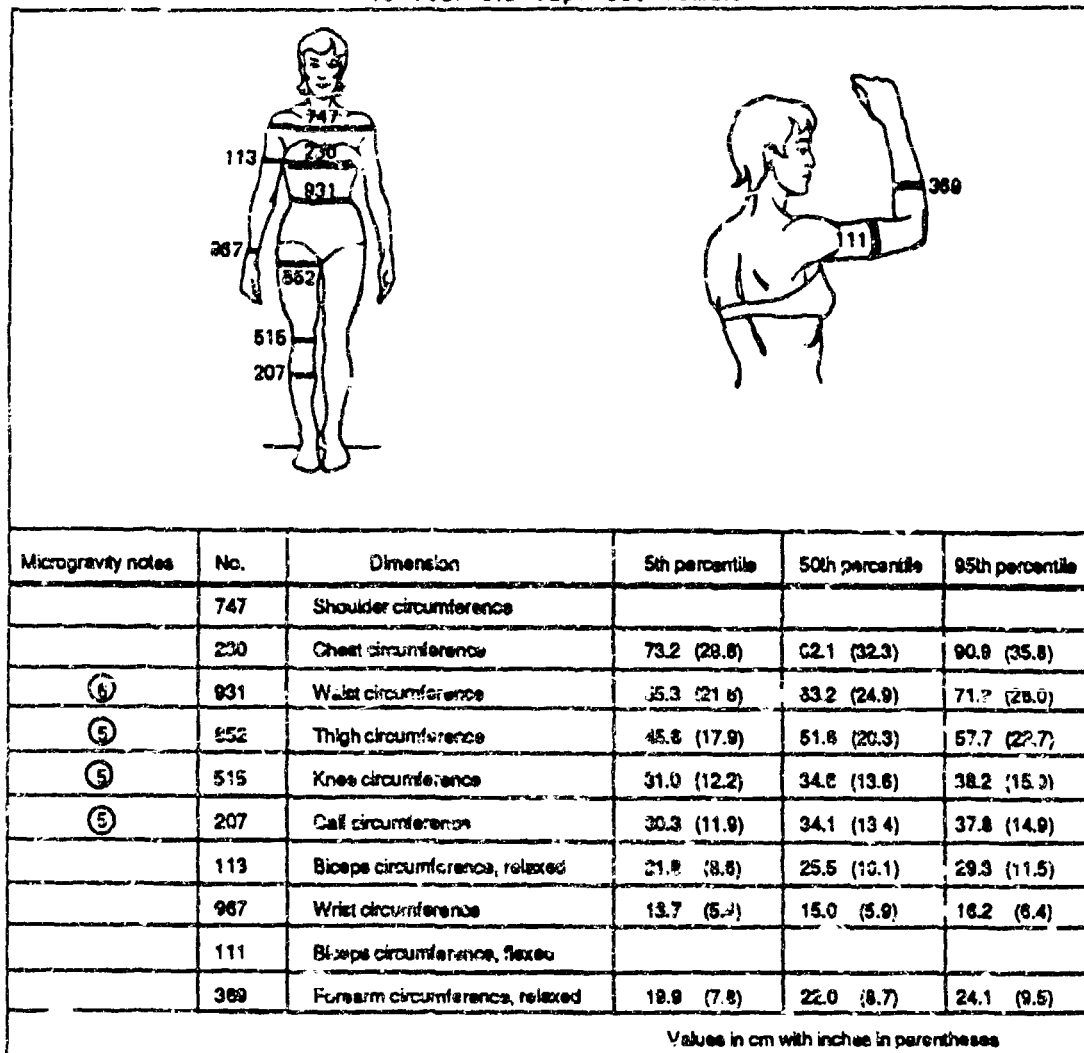
- ① Stature increases approximately 3% over the first 3 to 4 days in weightlessness (see Figure 3.2.3.1-2). Almost all of this change appears in the spinal column, and thus affects 'increases' other related dimensions, such as sitting height (buttock-vertex), shoulder height - sitting, eye height - sitting, and all dimensions that include the spine.
- ③ Shoulder or acromial height, sitting or standing, increases during weightlessness due to two factors:
 - a) Removal of the gravitational pull on the arms.
 - b) Extension of the spinal column as explained in note 1 above (3% of stature on ground).

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old Japanese Female



Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

- ⑤ Leg circumferences and diameters significantly decrease during the first day in microgravity. See Reference 16, Appendix C, for details and measurements of actual persons.
- ⑥ Waist circumference will decrease in microgravity due to fluid shifts to the upper torso. See Figure 3.2.3.1-2 for measurements on actual persons.

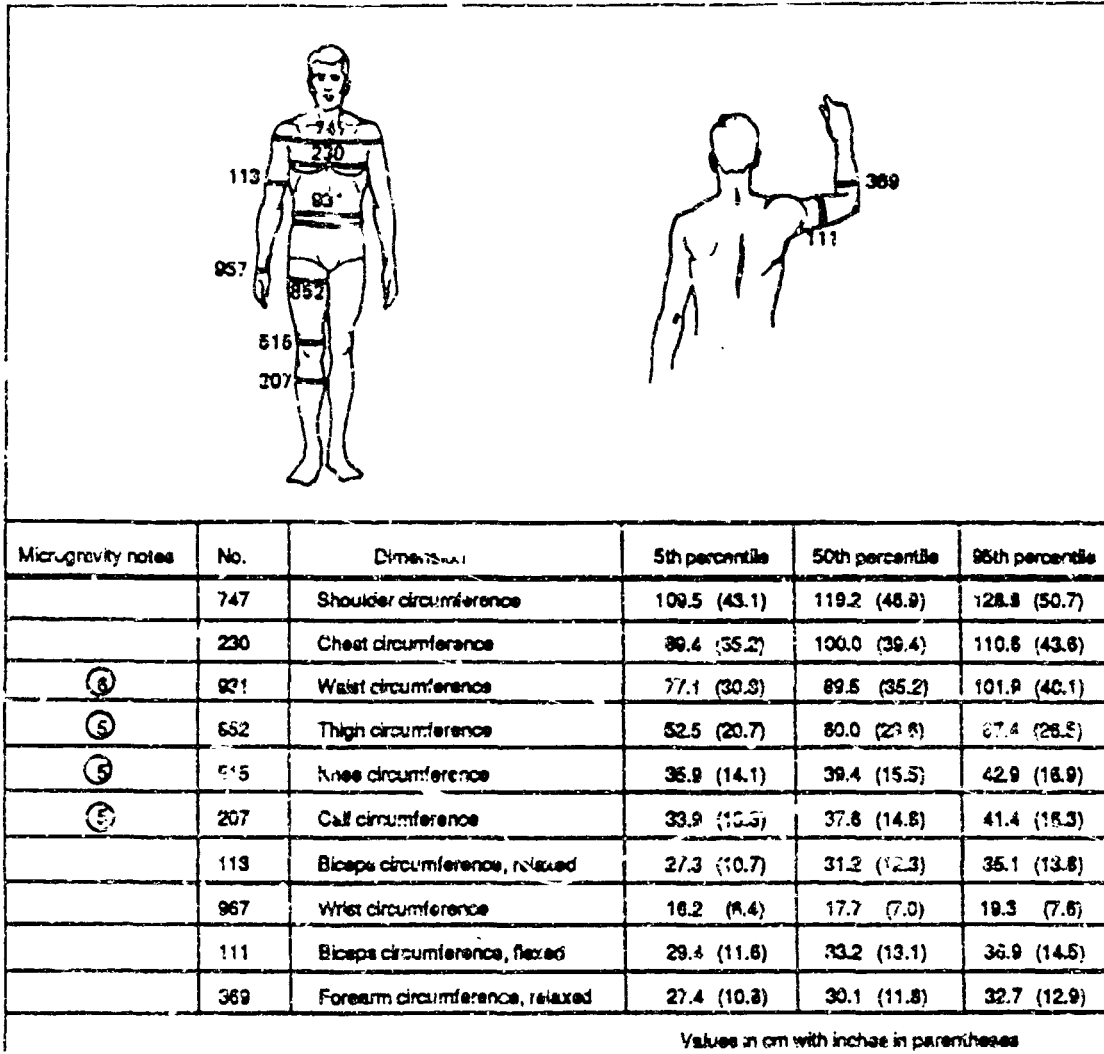
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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old American Male

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Notes:

A) Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

B) Application of dimensions to microgravity conditions:

- ⑤ Leg circumferences and diameters significantly decrease during the first day in microgravity. See Reference 16, Appendix C, for details and measurements of actual persons.
- ⑥ Waist circumference will decrease in microgravity due to fluid shifts to the upper torso. See Figure 3.2.3.1-2 for measurements on actual persons.

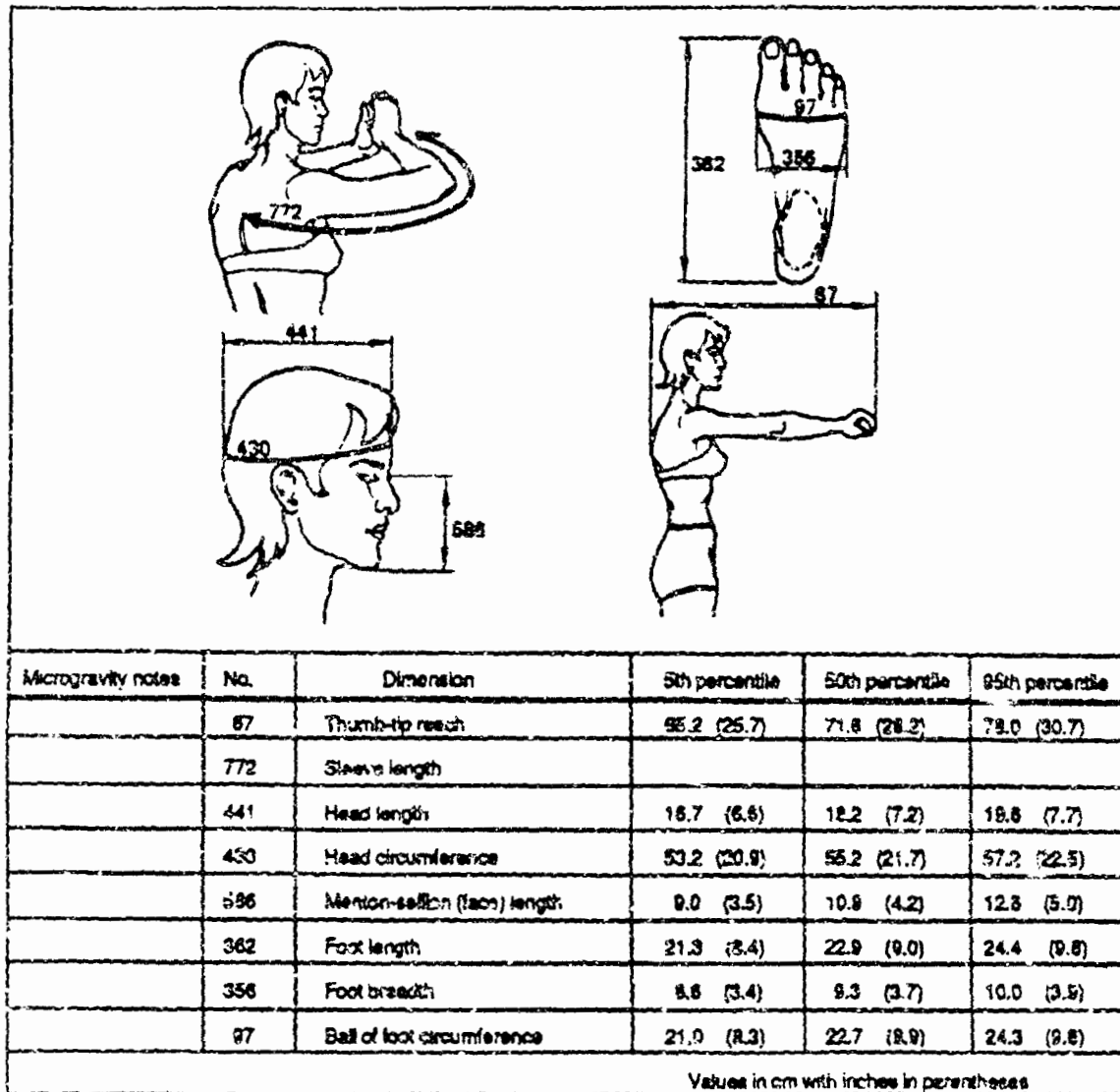
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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Females for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old Japanese Female



Notes:

Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

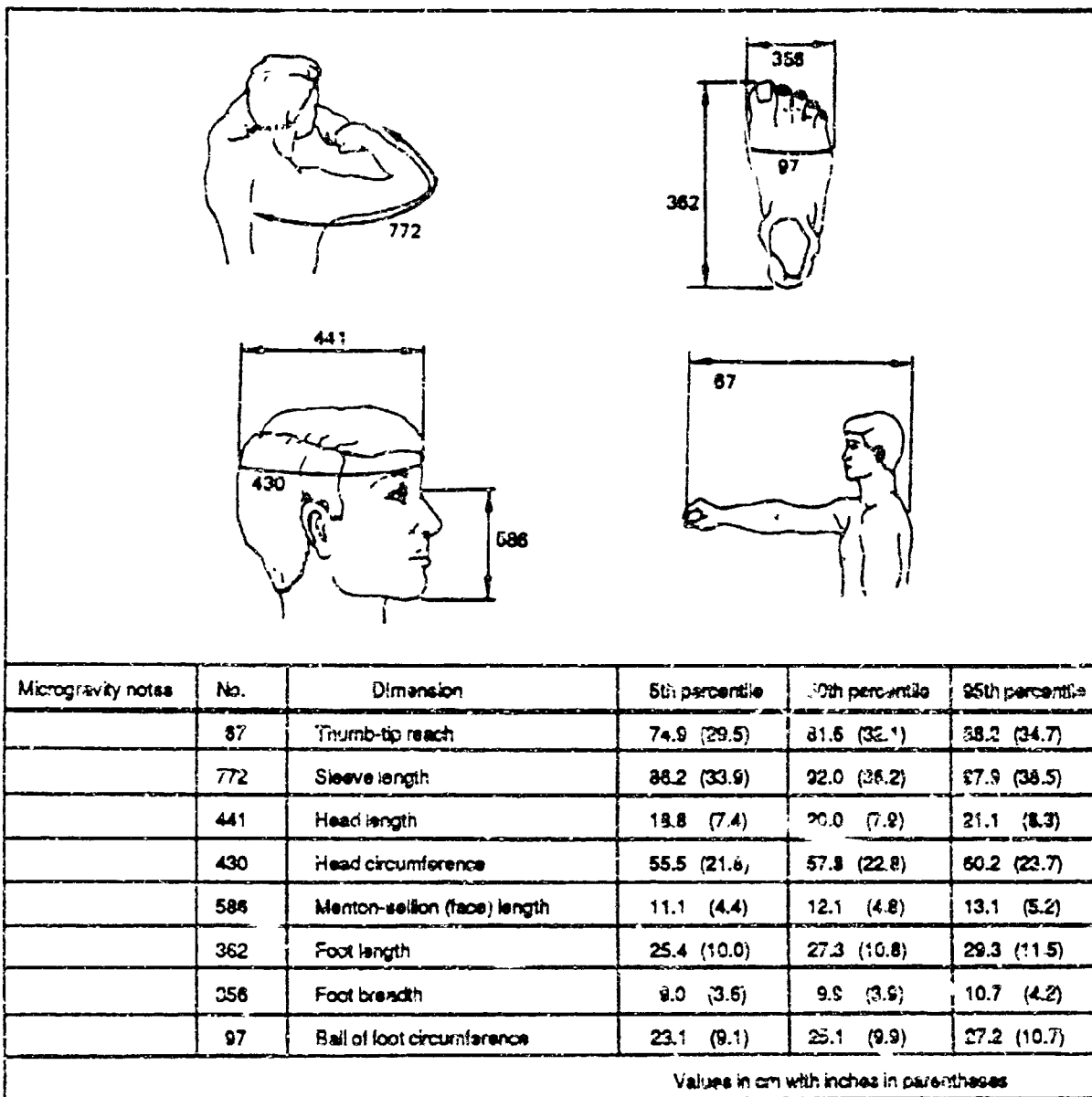
Reference: 274, Page 121-128

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Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

40-Year-Old American Male



Notes:

Measurement data - The numbers adjacent to each of the dimensions are reference codes. The same codes are in Volume II of Reference 16. Reference 16, Volume II, provides additional data for these measurements plus an explanation of the measurement technique.

Reference: 274, Page 121-128

308

351

76 2681

Figure 3.3.1.3-1 Body Size of the 40-Year-Old American Male and 40-Year-Old Japanese Female for Year 2000 in One Gravity Conditions (Continued)

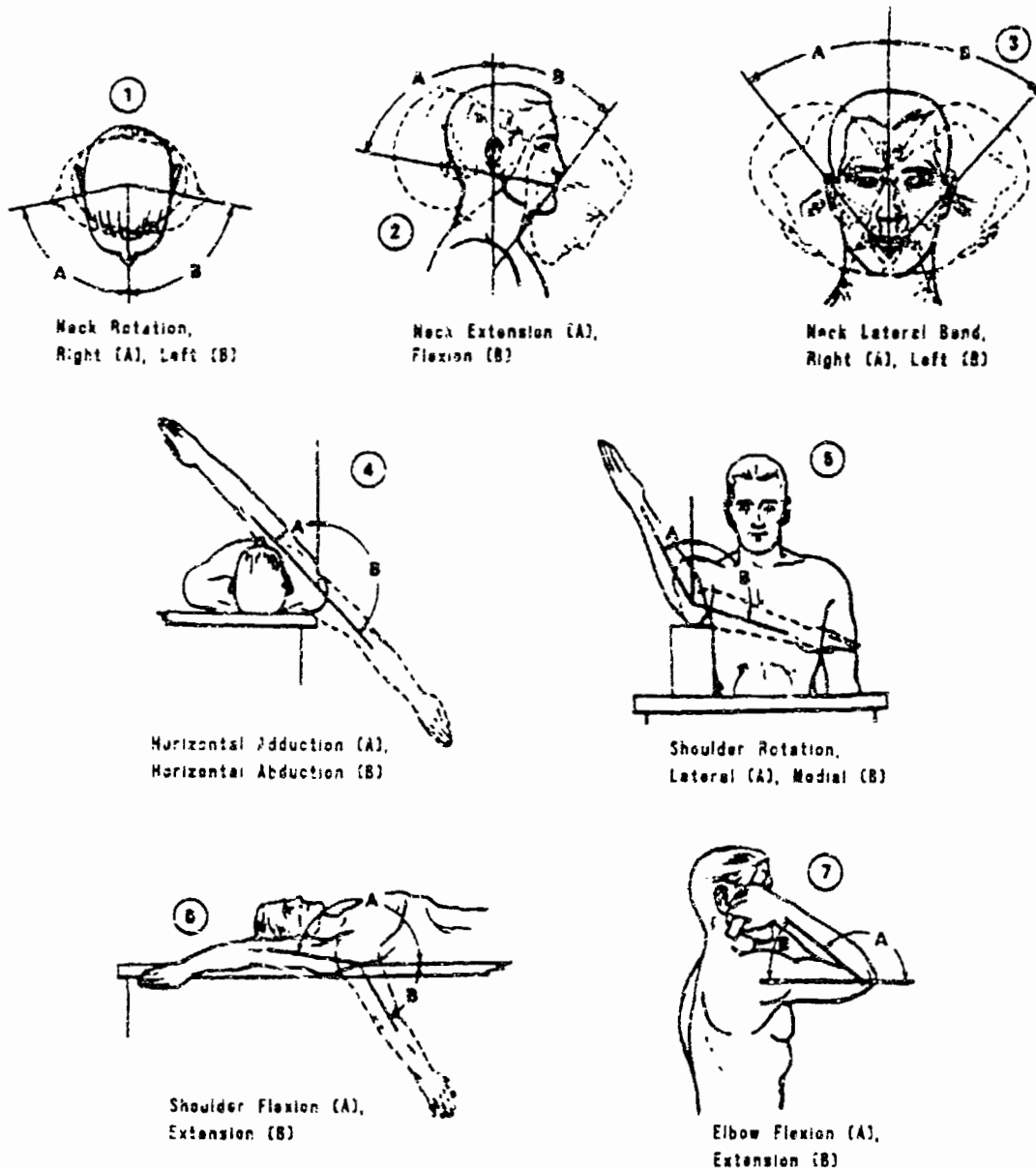
Figure	Joint movement (note b)	Range of motion (degrees)			
		Males (note a)		Females (note a)	
		5th percentile	95th percentile	5th percentile	95th percentile
①	Neck, rotation right	73.3	99.6	74.9	108.8
	Neck, rotation left	74.3	99.1	72.2	109.0
②	Neck, flexion	34.5	71.0	46.0	84.4
	Neck, extension	65.4	103.0	64.9	103.0
③	Neck, lateral right	34.9	63.5	37.0	63.2
	Neck, lateral left	35.5	63.5	29.1	77.2
④	Shoulder, abduction	173.2	188.7	172.6	192.9
⑤	Shoulder, rotation lat	46.3	96.7	53.8	95.8
	Shoulder, rotation med	90.5	126.6	95.8	130.9
⑥	Shoulder, flexion	164.4	210.9	162.0	217.0
	Shoulder, extension	39.3	83.3	33.7	87.9
⑦	Elbow, flexion	140.5	159.0	144.9	165.9
⑧	Forearm, pronation	78.2	116.1	82.3	118.9
	Forearm, supination	83.4	125.8	90.4	139.5
⑨	Wrist, radial	16.9	36.7	16.1	36.1
	Wrist, ulnar	18.6	47.9	21.5	43.0
⑩	Wrist, flexion	61.5	94.8	68.2	98.1
	Wrist, extension	40.1	78.0	42.3	74.7
⑪	Hip, flexion	116.5	148.0	118.5	145.0
⑫	Hip, abduction	26.8	53.5	27.2	55.9
⑬	Knee, flexion	116.4	145.8	125.2	145.2
⑭	Ankle, plantar	36.1	79.8	44.2	91.1
	Ankle, dorsal	8.1	19.9	8.9	17.4

Reference: 365, Figure 3.711 to 713
111

- Notes: a. Data was taken 1979 and 1980 at NASA-JSC by Dr. William Thornton and John Jackson. The study was made using 192 males (mean age 33) 22 females (mean age 30) astronaut candidates (see Reference 365)
b. Limb range is average of right and left limb movement.

Figure 3.3.2.3.1-1 Joint Movement Ranges for Males and Females

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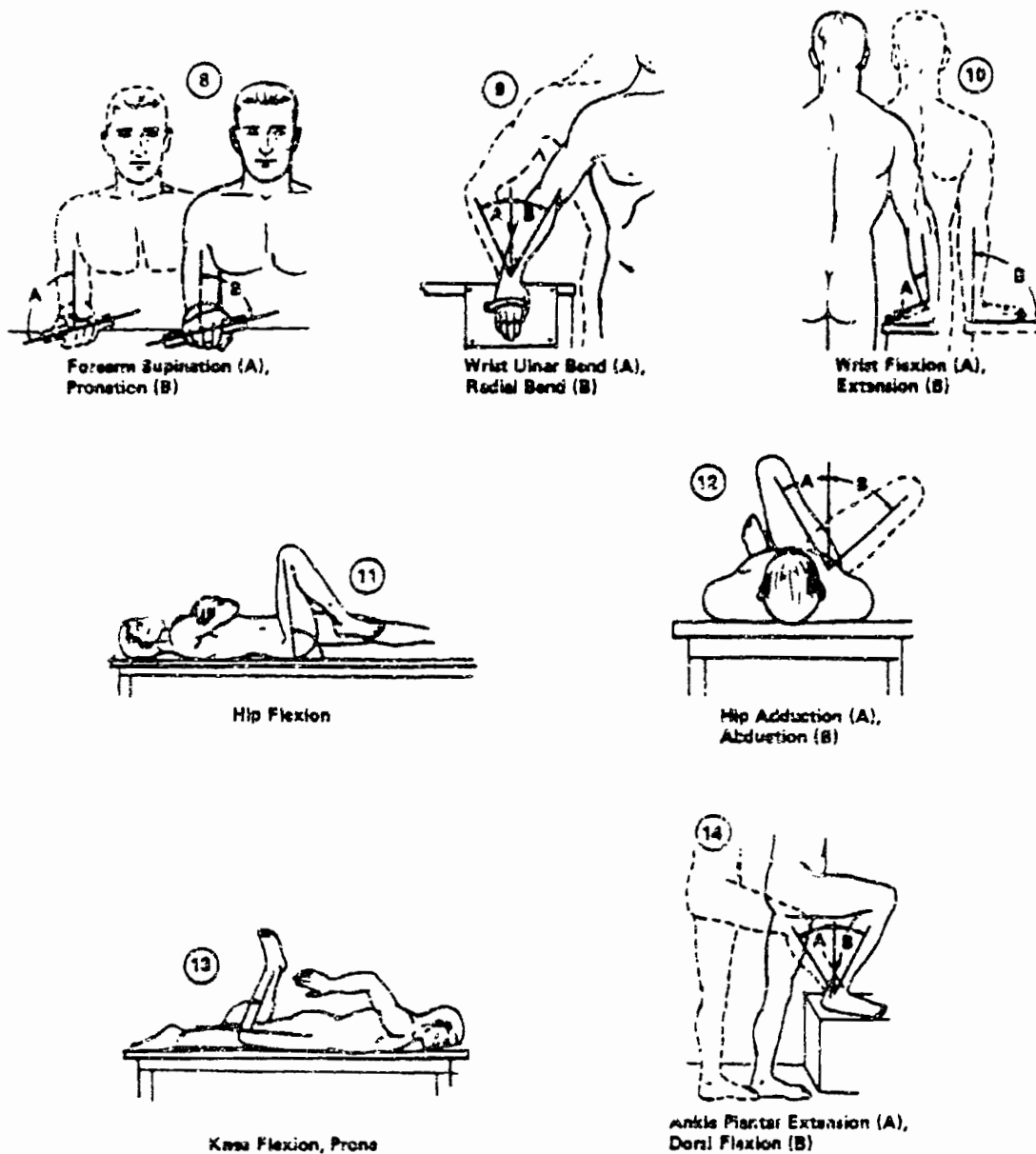


Reference: 365, Figures 711 to 713 With Updates
111

Notes: Data was taken 1979 and 1980 at NASA-JSC by Dr. William Thornton and John Jackson. The study was made using 192 males (mean age 33) 22 females (mean age 30) astronaut candidates (see Reference 365)

Figure 3.3.2.3.1-1 Joint Movement Ranges for Males and Females (Continued)

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Reference: 365, Figures 711 to 713
111

Notes: Data was taken 1979 and 1980 at NASA-JSC by Dr. William Thornton and John Jackson. The study was made using 192 males (mean age 33) 22 females (mean age 30) astronaut candidates (see Reference 365)

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Figure 3.3.2.3.1-1 Joint Movement Ranges for Males and Females (Continued)

3.3.2.3.2 Joint Motion Data, Two Joints Design Requirements

The range of movement for two joints is given in this paragraph. The changes in range of motion of a given joint when supplemented by the movement of an adjacent joint are summarized in Figure 3.3.2.3.2-1. The following information is given in this Figure:

- a. Single Joint Movement Baseline Range - The baseline values of given joint motions with the adjacent joint in neutral position.
- b. Effect (in Degrees) of Movement of an Adjacent Joint - The increment or decrement which takes place when an adjacent joint is flexed or extended in varying amounts (1/3, 1/2, 2/3 and/or full).
- c. Effect (in Terms of Percent of the Baseline Range) of Movement of an Adjacent Joint.

3.3.3 Reach

3.3.3.1 Introduction - N/A

3.3.3.2 Reach Design Considerations - N/A

3.3.3.3 Reach Data Design Requirements

The data in this section shall be used as appropriate to achieve effective integration of the crew and the Assured Crew Return Vehicle. (See section 4.10 for Effects of Deconditioning.)

3.3.3.3.1 Functional Reach Design Requirements

Equipment and controls required to perform a task shall be within the reach limit of the crewmember performing the task. The following is the functional reach limit data for persons wearing non-restrictive clothing. (For additional restrictions due to the crew deconditioned effects, refer to section 4.10, Deconditioned Crew Capabilities).

- a. Torso Restrained Reach Boundaries - The functional reach boundaries for males and females with their shoulders against a flat backrest are given in Figure 3.3.3.3.1-1. The functional reach boundaries apply to tasks requiring thumb and forefinger grasp. Figure 3.3.3.3.1-3 defines adjustment for other grasp requirements.
- b. Waist Restrained - Adjustments can be made to the data in Figure 3.3.3.3.1-1 for bending at the waist to achieve different back rest angles. Figure 3.3.3.3.1-2 provides data for making these best angle adjustments. This data applies to 1-g conditions only, and requires adjustments for spinal lengthening in microgravity.

3.3.4 Neutral Body Posture - N/A

Two-joint movement	Full range of A (degrees)	Change in range of movement of A (degrees)				
		Movement of B (fraction of full range)				
		Zero	1/3	1/2	2/3	Full
Shoulder extension (A) with elbow flexion (B)	59.3 deg		+1.6 deg (102.7%)		+0.9 deg (101.5%)	+5.3 deg (108.2%)
Shoulder flexion (A) with elbow flexion (B)	180.7 deg		-24.3 deg (86.9%)		-38.1 deg (81.0%)	-47.4 deg (75.0%)
Elbow flexion (A) with shoulder extension (A)	152.2 deg			-3.78 deg (97.5%)		-1.22 deg (99.2%)
Elbow flexion (A) with shoulder flexion (B)	152.2 deg		-0.6 deg (99.6%)		-0.8 deg (99.5%)	-69.0 deg (54.7%)
Hip flexion (A) with shoulder flexion (B)	53.3 deg	-35.6 deg* (33.2%)	-24.0 deg (55.0%)		-6.2 deg (88.4%)	-12.3 deg (76.9%)
Ankle plantar flexion (A) with knee flexion (B)	48.0 deg		-3.4 deg (92.8%)		+0.2 deg (100.4%)	+1.6 deg (103.3%)
Ankle dorsiflexion (A) with knee flexion (B)	28.1 deg		-7.3 deg (72.0%)		-2.7 deg (89.7%)	-3.2 deg (87.7%)
Knee flexion (A) with ankle plantar flexion (B)	127.0 deg			-8.9 deg (92.2%)		-4.7 deg (96.3%)
Knee flexion (A) with ankle dorsiflexion (B)	127.0 deg					-8.7 deg (93.0%)
Knee flexion (A) with hip flexion (B)	127.0 deg			-19.6 deg (84.6%)		-33.6 deg (73.5%)

*The knee joint is locked and the unsupported leg extends out in front of the subject.

Reference: 16, pages VI-12 to VI-15

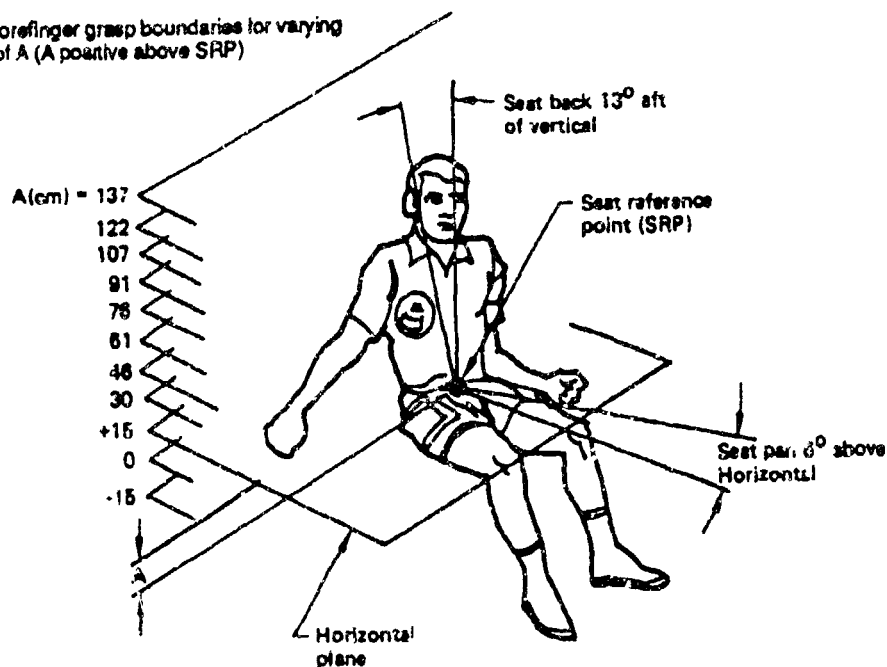
Note:

The following is an example of how the Figure is to be used. The first entry is read as follows: the shoulder can be extended as far as 59.3 degrees (the mean of the subjects tested) with the elbow in a neutral position (locked in hyperextension). When shoulder extension was measured with the elbow flexed to 1/3 of its full joint range, the mean value of shoulder extension was found to increase by 1.6 degrees, or 102.7% of the base value. The results for other movements and adjacent joint positions are presented in a similar manner.

Figure 3.3.2.3.2-1 Change in Range of Movement With Movement in Adjacent Joint

Horizontal Plane

Thumb and forefinger grasp boundaries for varying dimensions of A (A positive above SRP)



- 5th percentile outer boundary and inner boundary (inner curve)
- 50th percentile outer boundary
- - - - - 95th percentile outer boundary

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Reference: 310, Pages 35 to 52

NOTES:

a. Gravity conditions - the boundaries apply to 1-G conditions on Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

b. Subjects - the subjects used for this study are representative of the 1967 Air Force population estimates defined in Reference 16, Chapter III

c. The Seat Reference Point (SRP), defined as the origin point for all reach limit measurements, is located at the junction of two planes which define the seat back and the seat pan, and a third plane which precisely bisects the subject's body front to back.

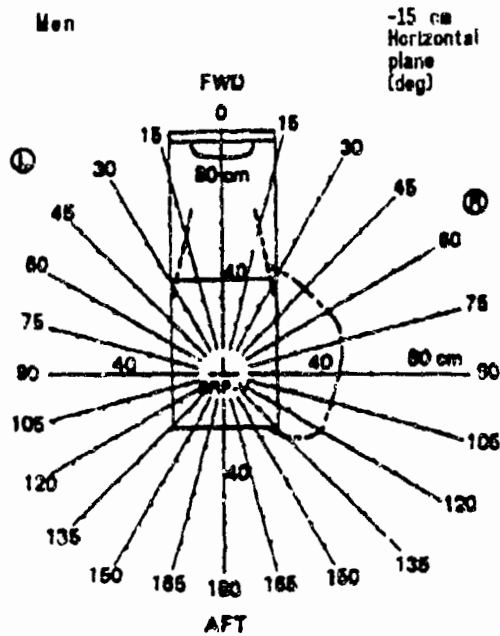
d. Each of the following diagrams represents a horizontal plane in which the reach limit of the subject (men, women) is determined. The vertical distance of this plane from the SRP is indicated in centimeters in the note in the upper right hand corner of each diagram. The subject is seated with respect to the SRP, as defined above. The radial extenders from the SRP projection on the plane of interest are labeled in degrees from the line extending directly forward from the subject. The numbers along these extenders (40, 80) represent distances in centimeters from the point on the plane of interest at which the SRP is projected.

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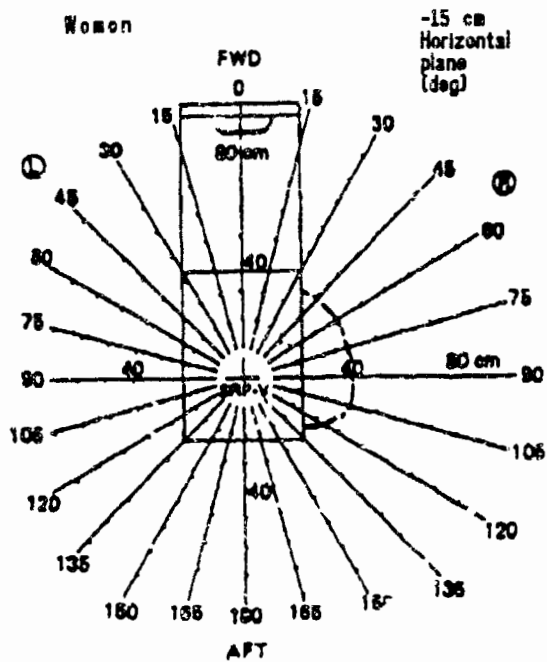
Figure 3.3.3.1-1 Grasp Reach Limits With Right Hand for American Male and Female Populations

Horizontal Plane

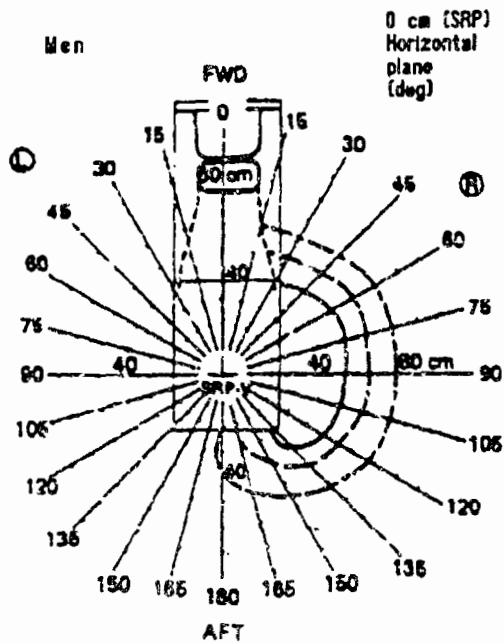
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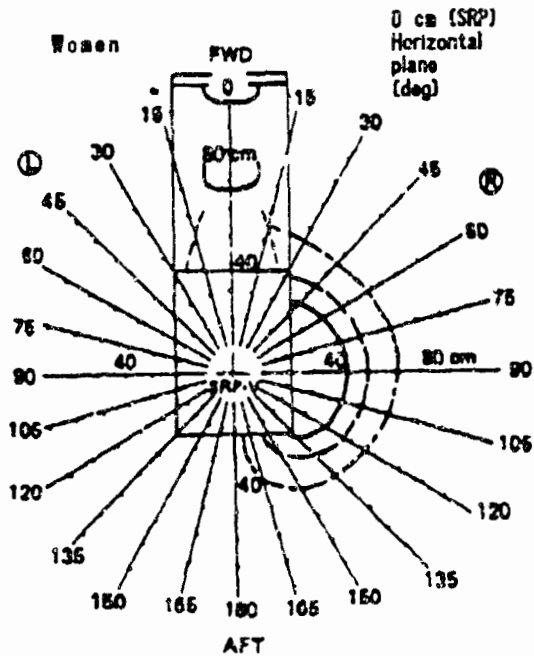
Women



Men

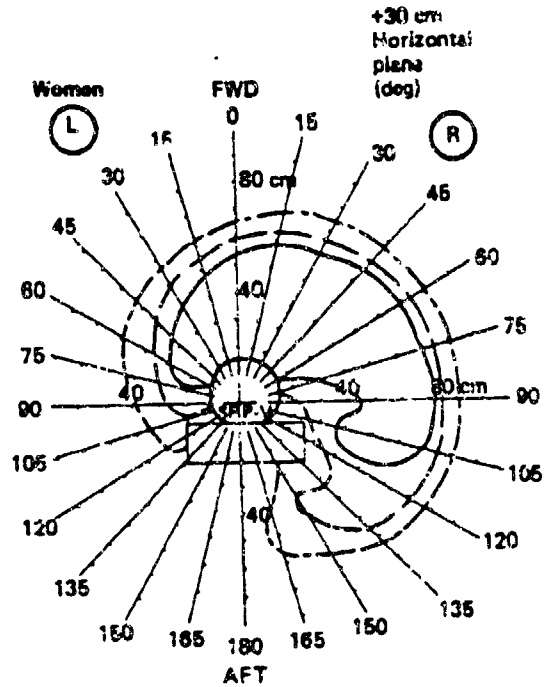
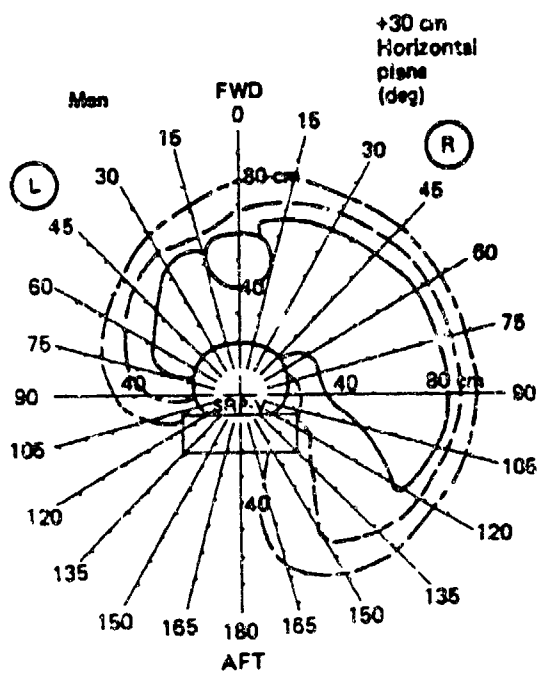
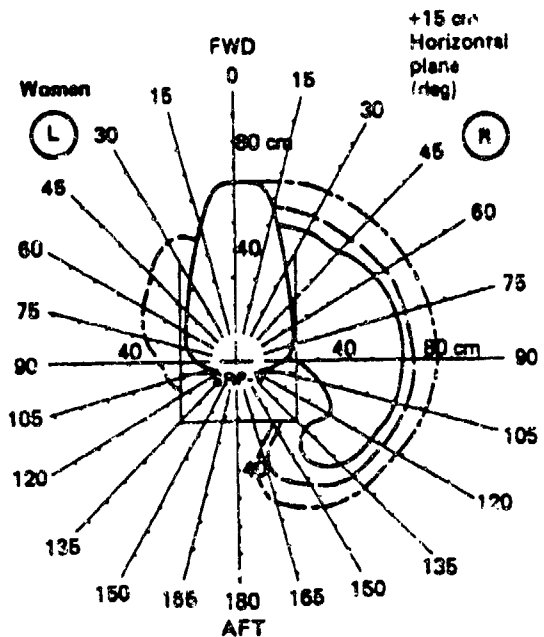
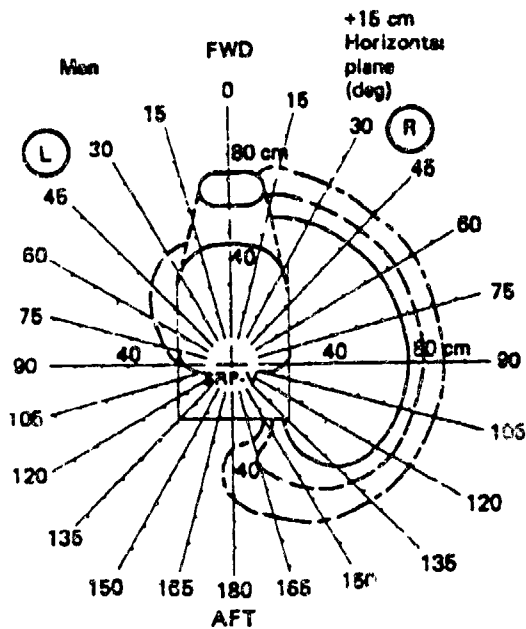


Women



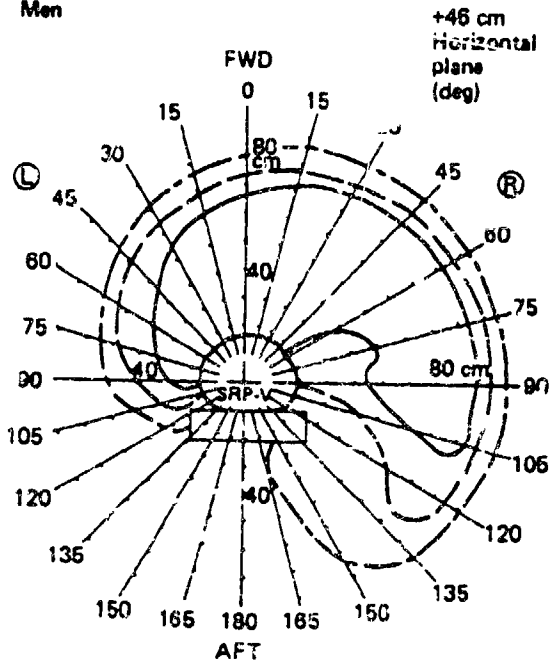
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Horizontal Plane

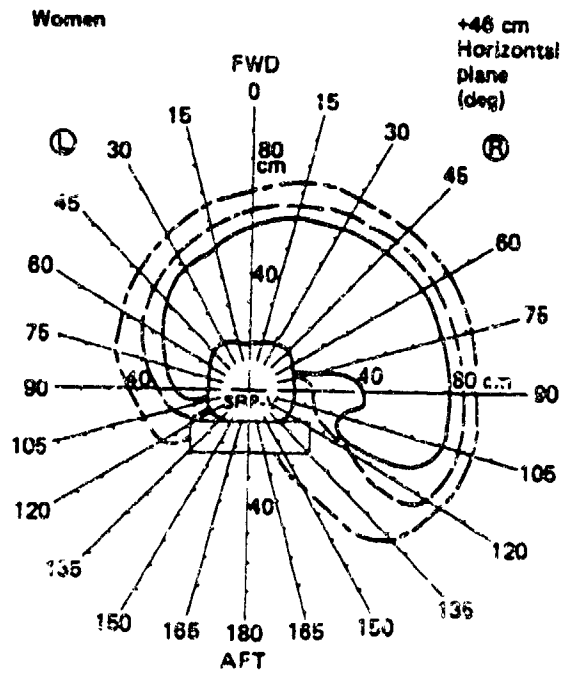


Horizontal Plane

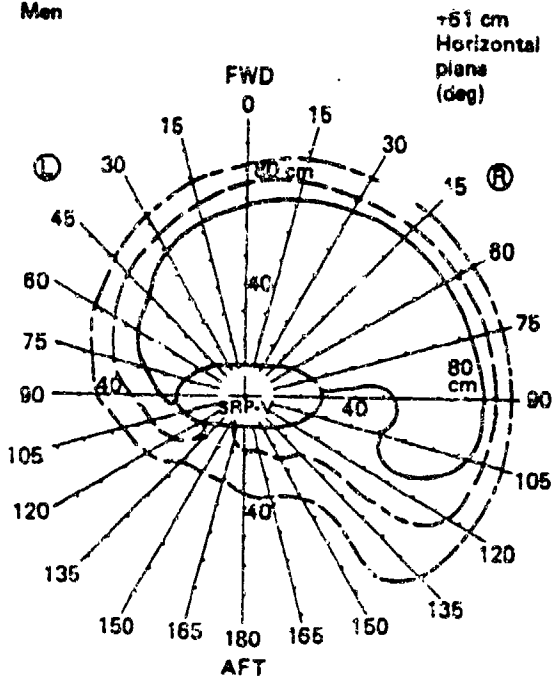
Men



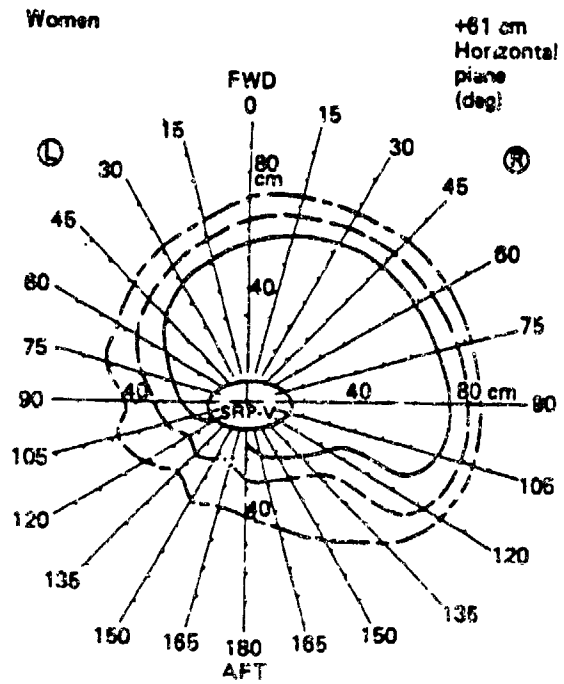
Women



Men

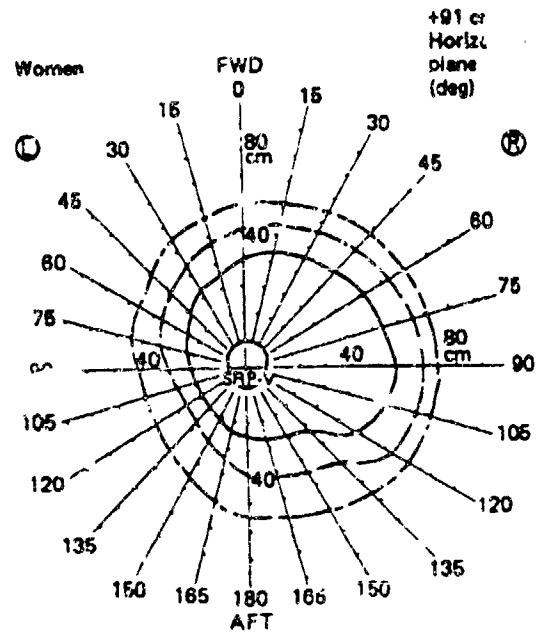
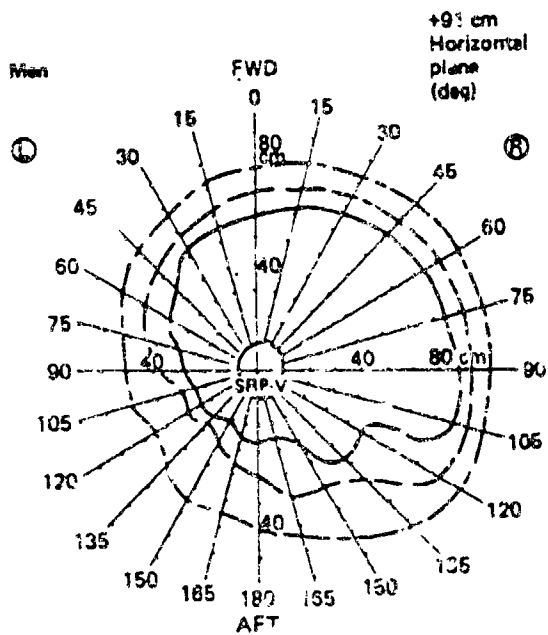
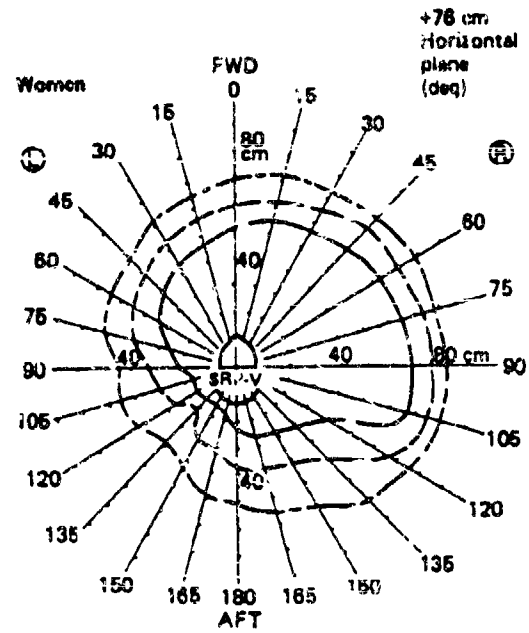
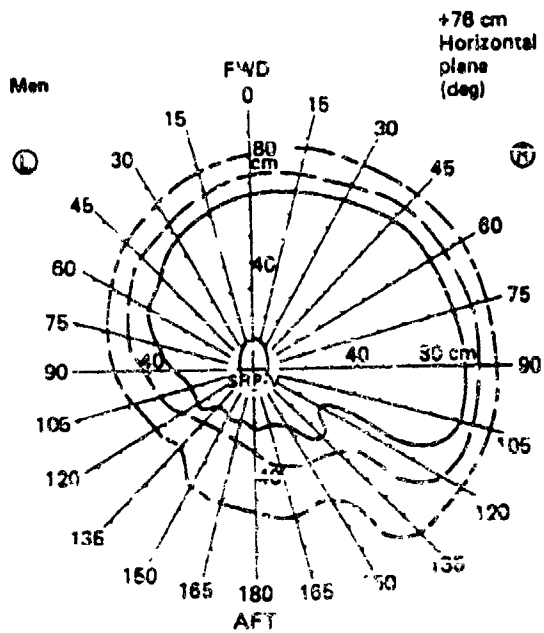


Women



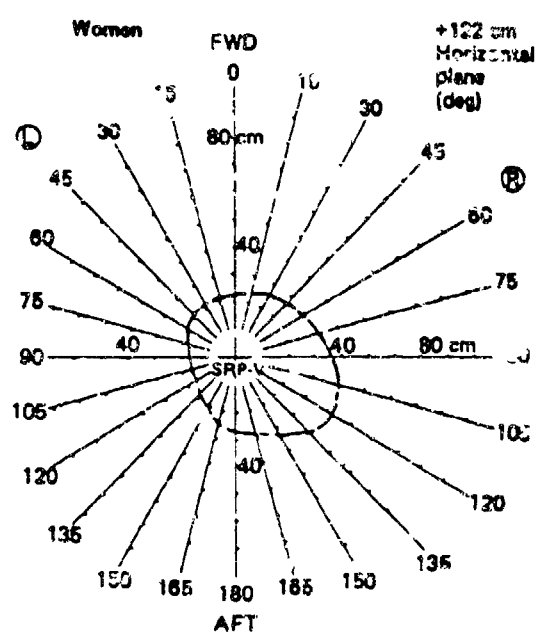
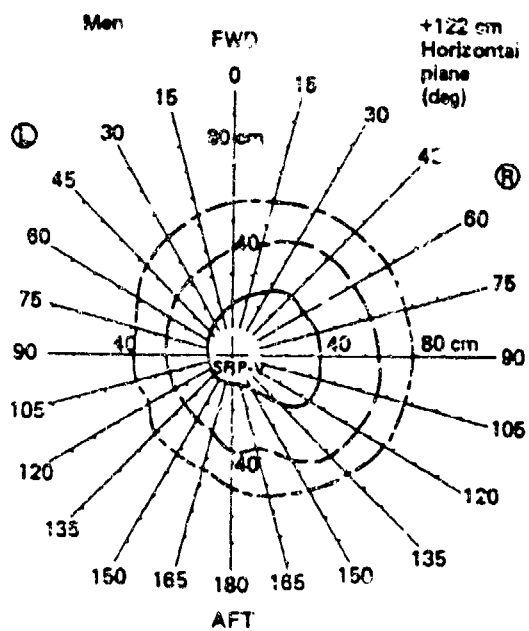
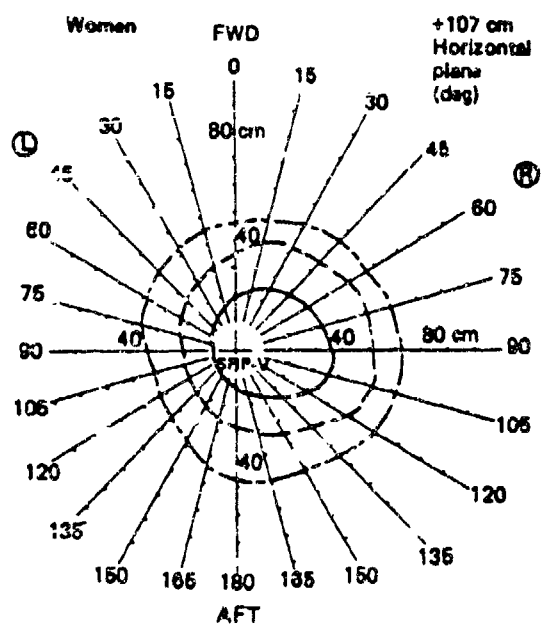
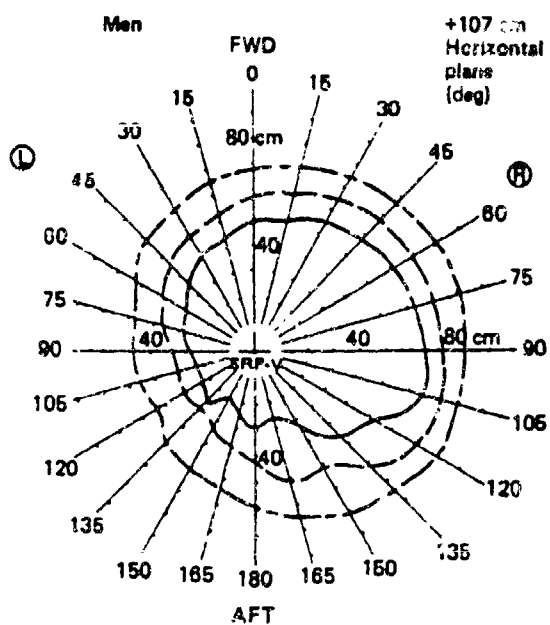
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Horizontal Plans



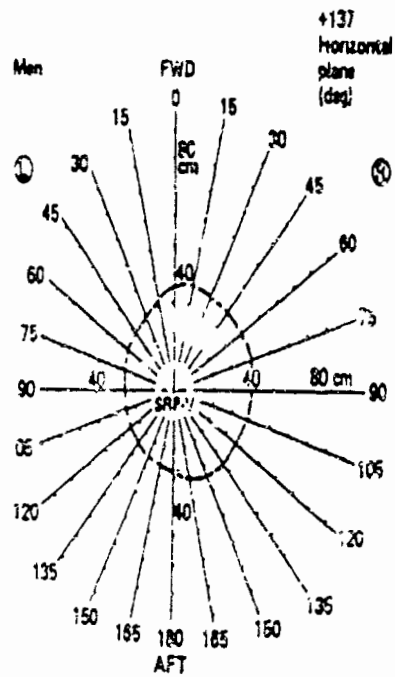
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Horizontal Plane



882 SA

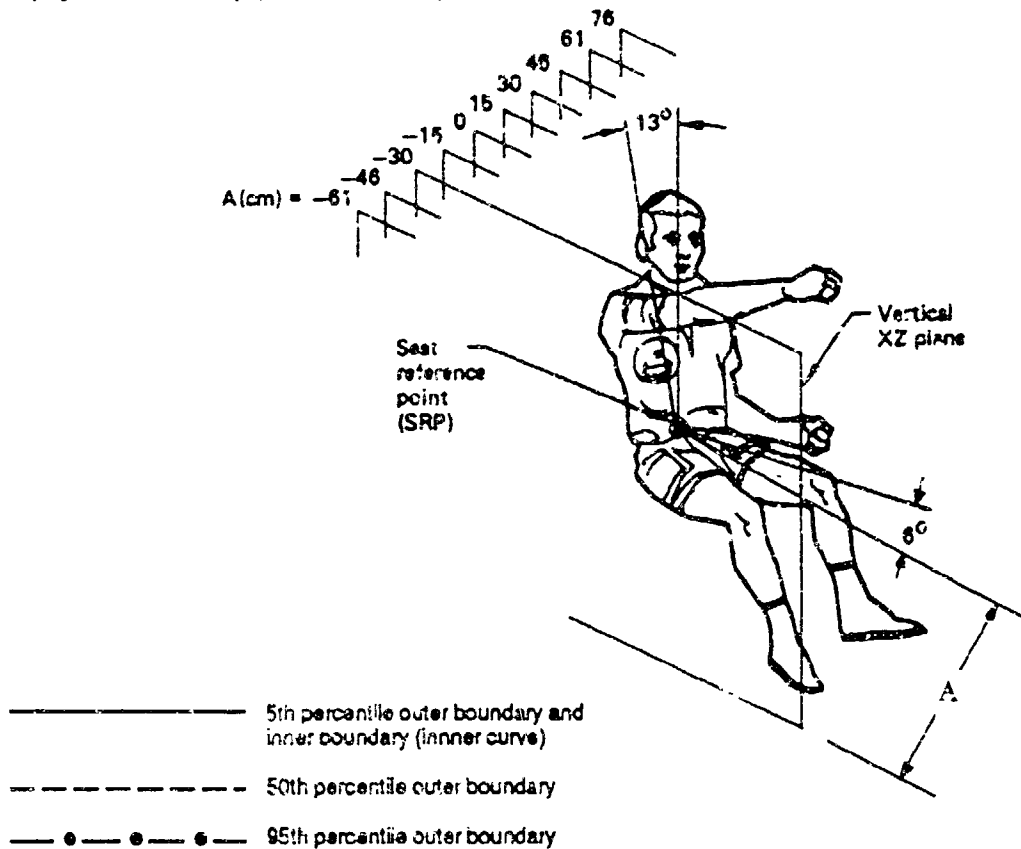
Horizontal Plane



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XZ Plane

Thumb and forefinger grasp boundaries for
varying dimensions of A (A positive left of SRP)



Reference: 310, Pages 35 to 52

NOTES:

a. Gravity conditions - the boundaries apply to 1-G conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.

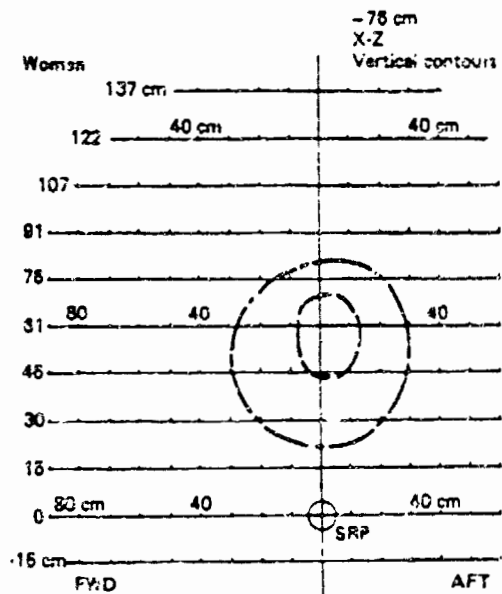
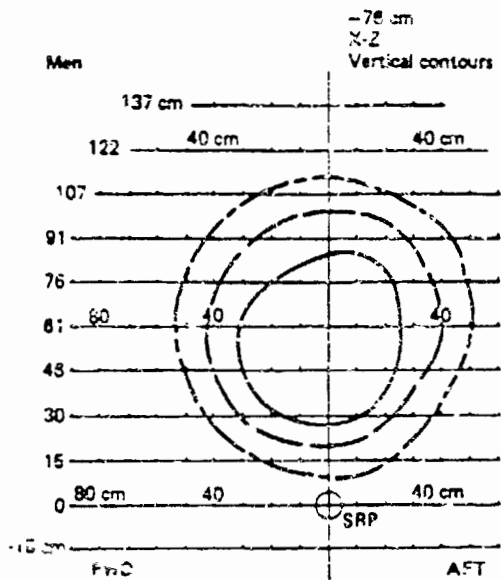
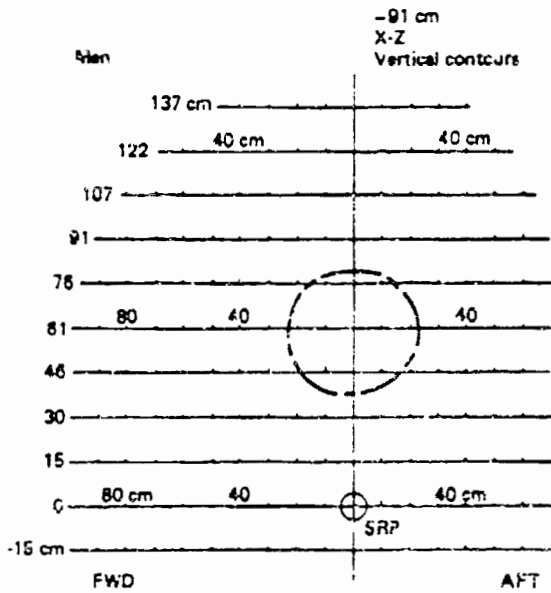
b. Subjects - the subjects used for this study are representative of the 1967 Air Force population estimates defined in Reference 16, Chapter III.

c. The Seat Reference Point (SRP), defined as the origin point for all reach limit measurements, is located at the junction of two planes which define the seat back and the seat pan, and a third plane which precisely bisects the subject's body front to back.

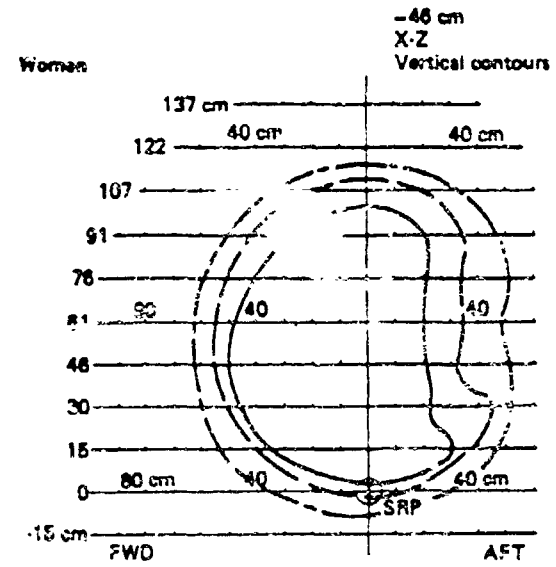
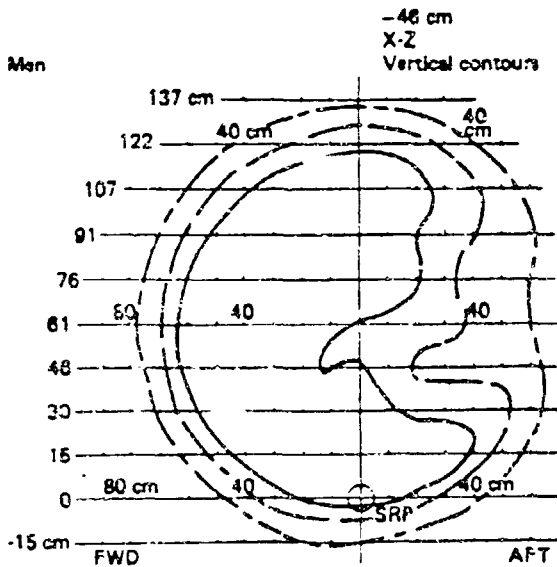
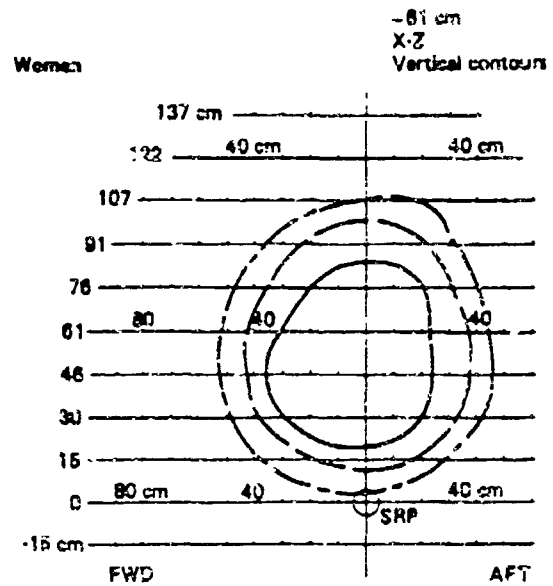
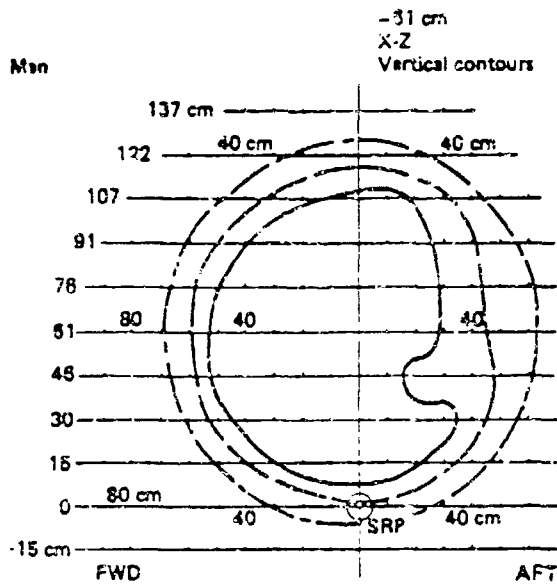
d. Each of the following diagrams represents an XZ plane projection in which the reach limit of the subject (men, women) is determined. This plane is perpendicular to both the "seat back" and the "seat pan" planes. The distance of this vertical plane from the SRP is indicated in centimeters in the note in the upper right hand corner of each diagram, negative numbers to the right and positive numbers to the left relative to the subject. The subject is seated with respect to the SRP, as defined above. The horizontal lines indicate vertical distances in centimeters from the SRP projection point on the plane of interest. The numbers located along the horizontal lines (40, 80) represent horizontal distances in centimeters, in this vertical plane from the SRP projection point on this plane.

Figure 3.3.3.1-1 Grasp Reach Limits With Right Hand for American Male and Female Populations (Continued)

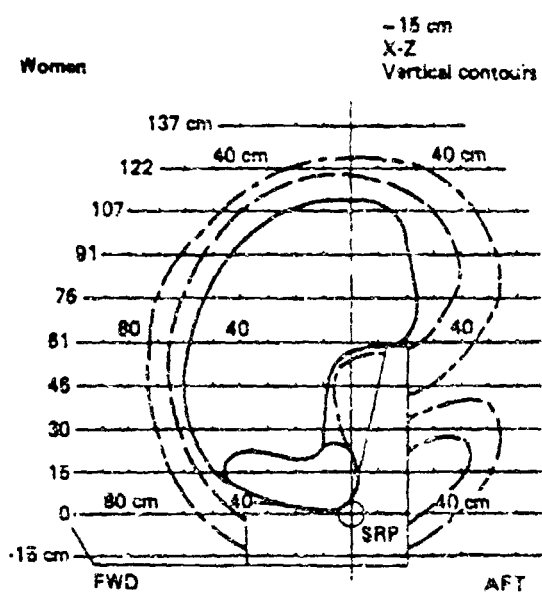
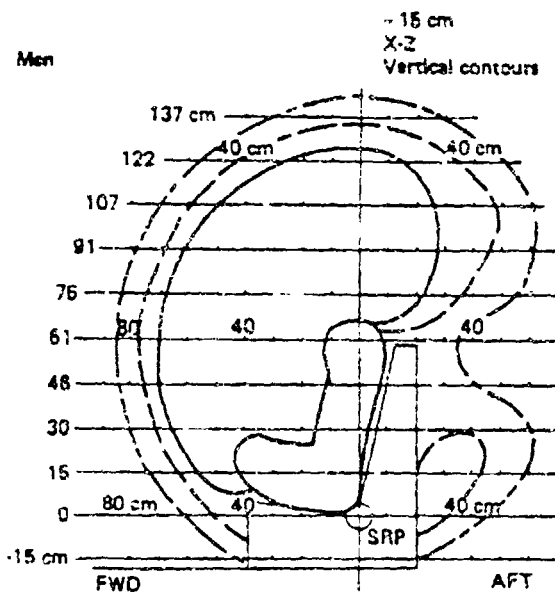
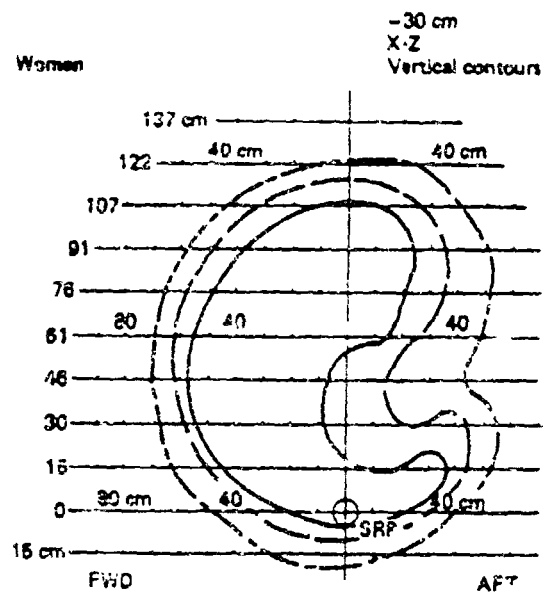
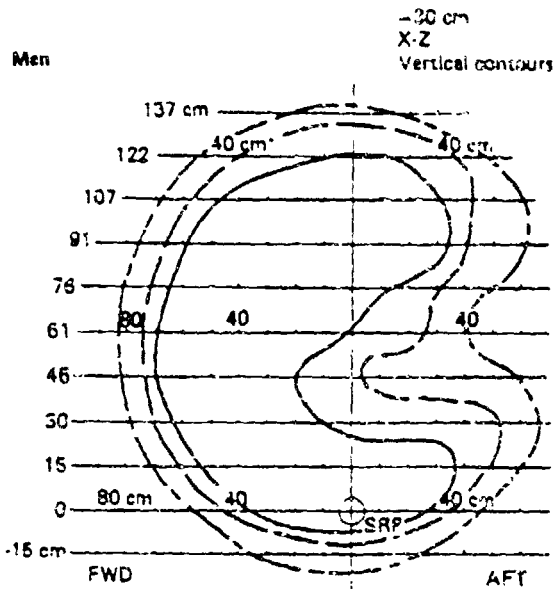
XZ Plane



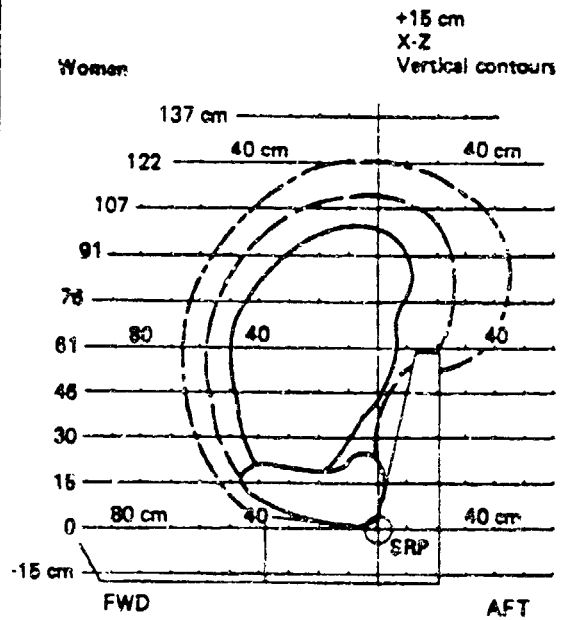
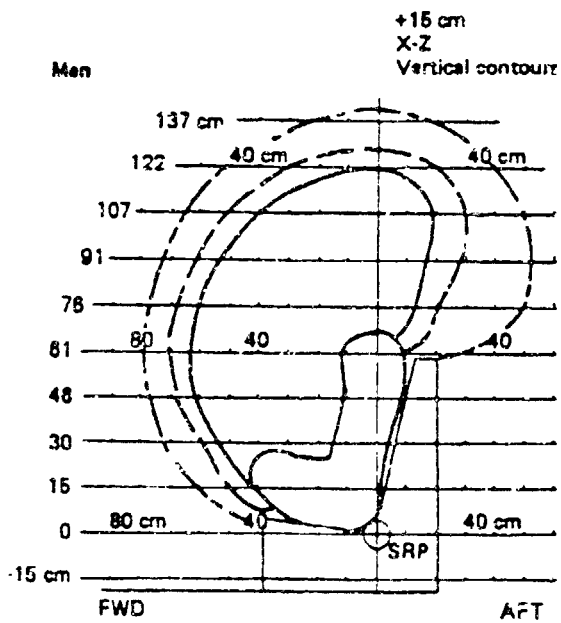
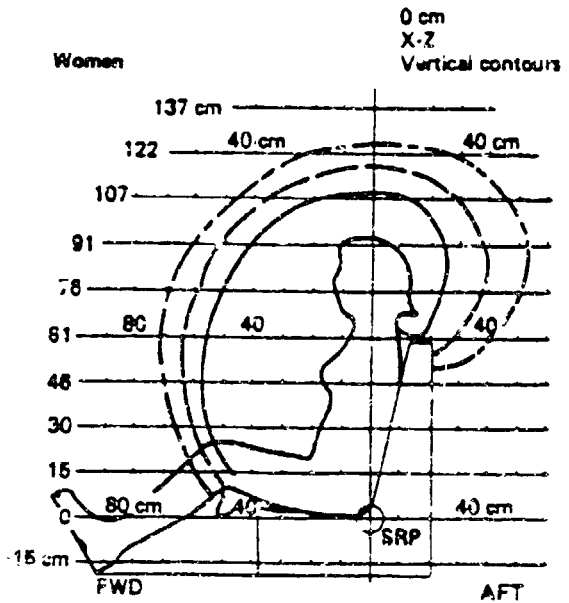
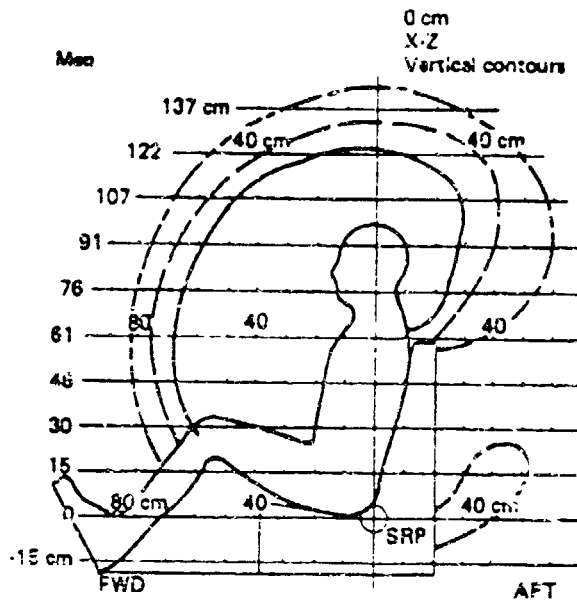
3-29
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XZ Plane

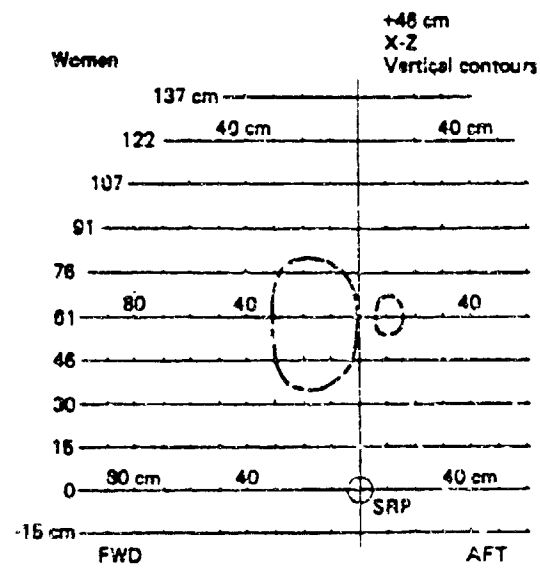
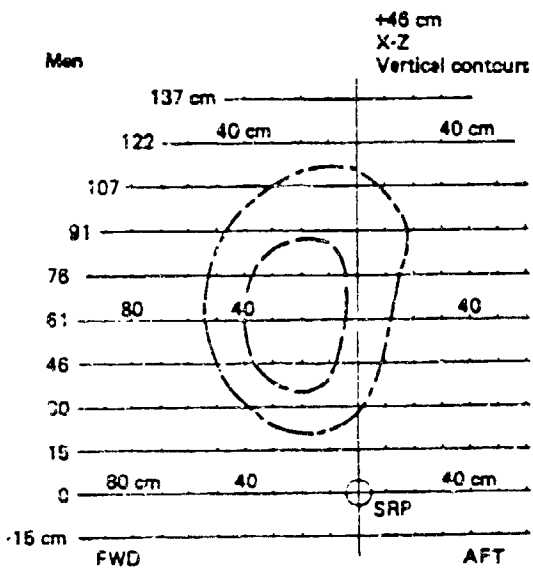
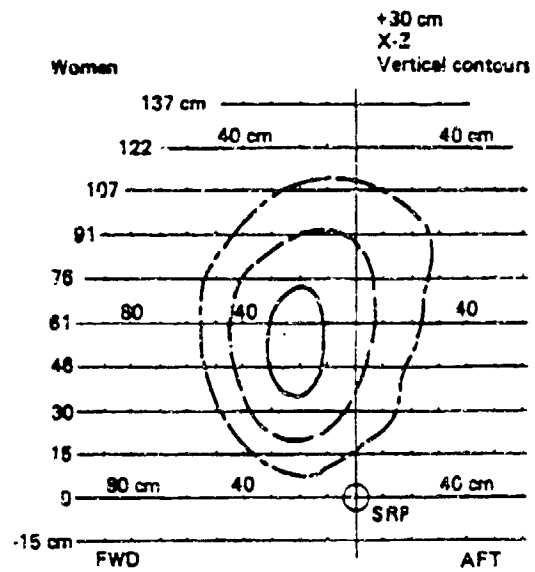
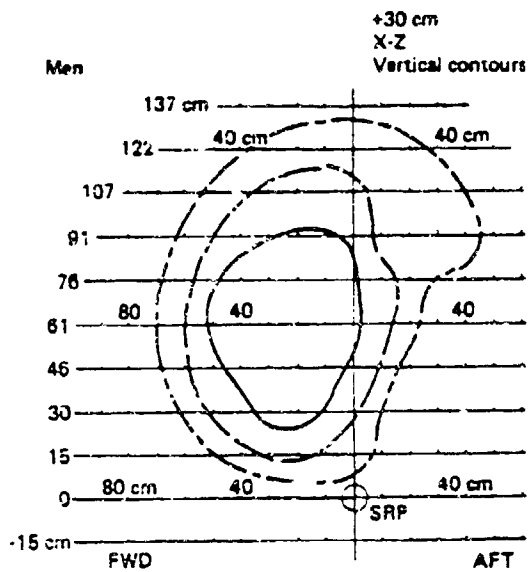
XZ Plane



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XZ Plane

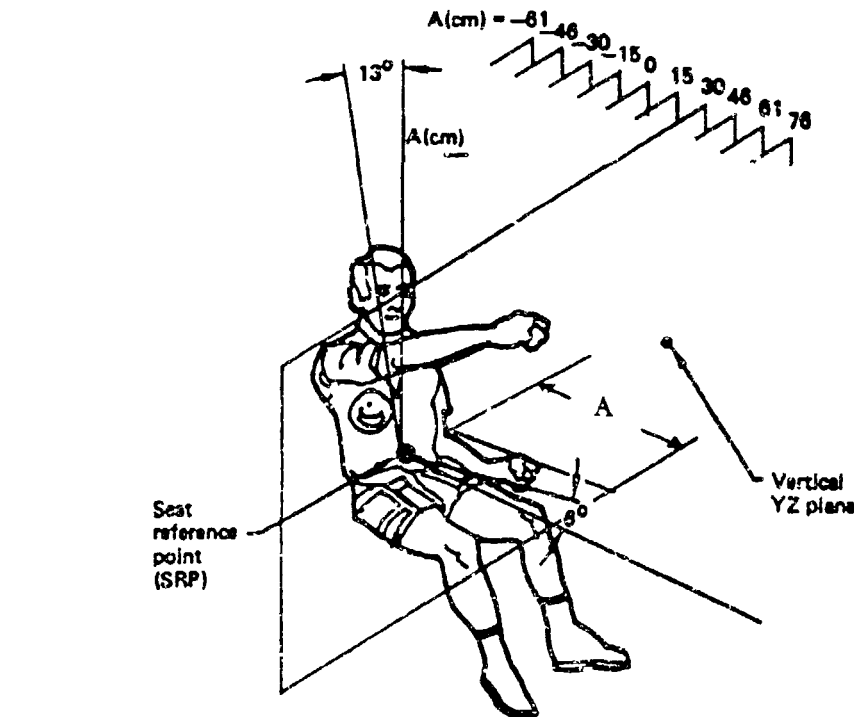
XZ Plane



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YZ Plane

Thumb and forefinger grasp boundaries for
varying dimensions of A (A positive fwd of SRP)



- 5th percentile outer boundary and
inner boundary (inner curve)
- 50th percentile outer boundary
- • — • — • — 95th percentile outer boundary

Reference: 310, Pages 35 to 52

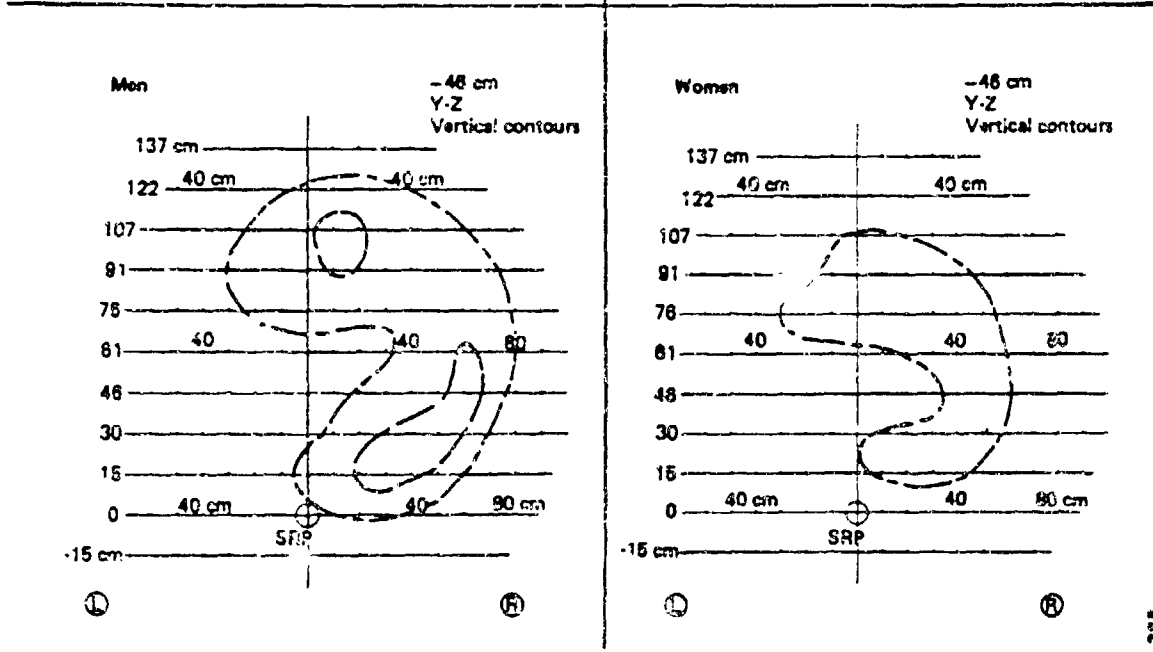
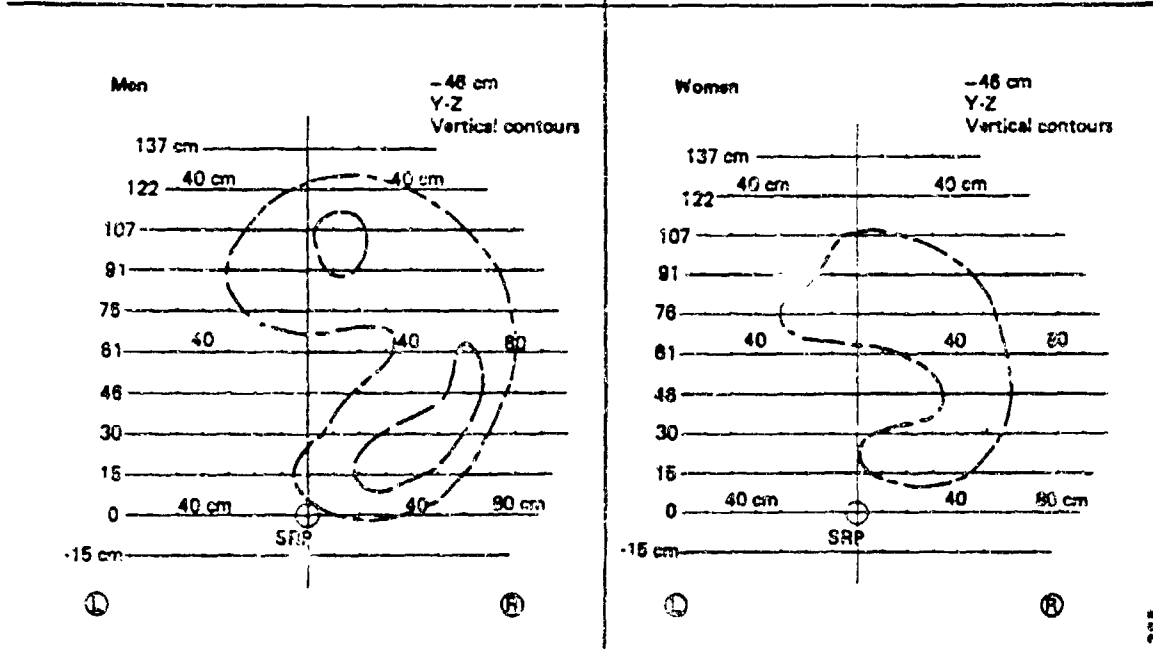
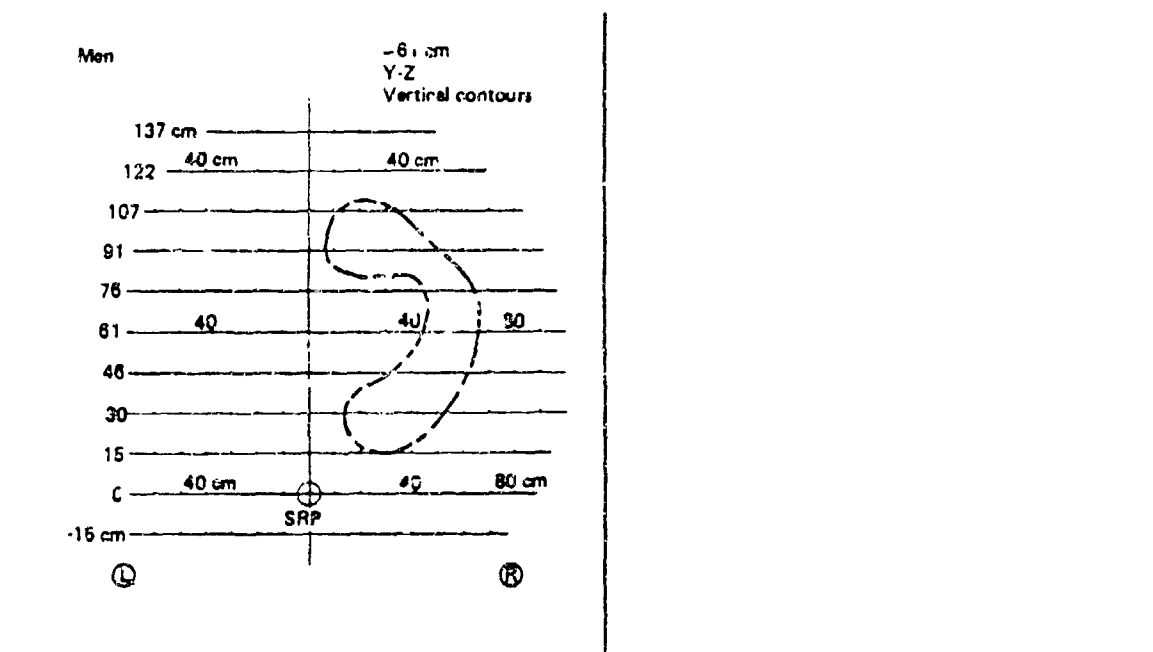
NOTES:

- a. Gravity conditions - the boundaries apply to 1-G conditions only. Microgravity will cause the spine to lengthen, and adjustments should be made based on a new shoulder pivot location.
- b. Subjects - the subjects used for this study are representative of the 1967 Air Force population estimates defined in Reference 16, Chapter III
- c. The Seat Reference Point (SRP), defined as the origin point for all reach limit measurements, is located at the junction of two planes which define the seat back and the seat pan, and a third plane which precisely bisects the subject's body front to back.
- d. Each of the following diagrams represents an YZ plane projection in which the reach limit of the subject (man, women) is determined. This is a vertical plane which is parallel to the line defined by the intersection of the "seat back" and "seat pan" planes. The distance of this plane from the SRP is indicated in centimeters in the note in the upper right hand corner of each diagram, negative numbers to the rear and positive numbers to the front relative to the subject. The subject is seated with respect to the SRP, as defined above. The horizontal lines indicate vertical distances in centimeters from the SRP projection point on the plane of interest. The numbers located along the horizontal lines (40, 80) represent horizontal distances in centimeters, in the vertical plane from the SRP projection point on this plane.

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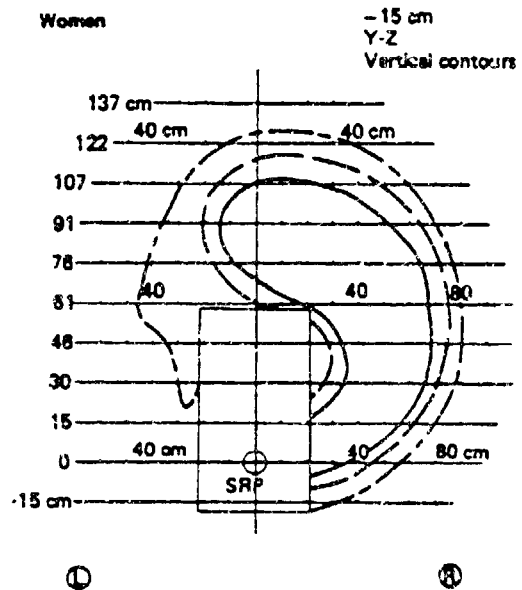
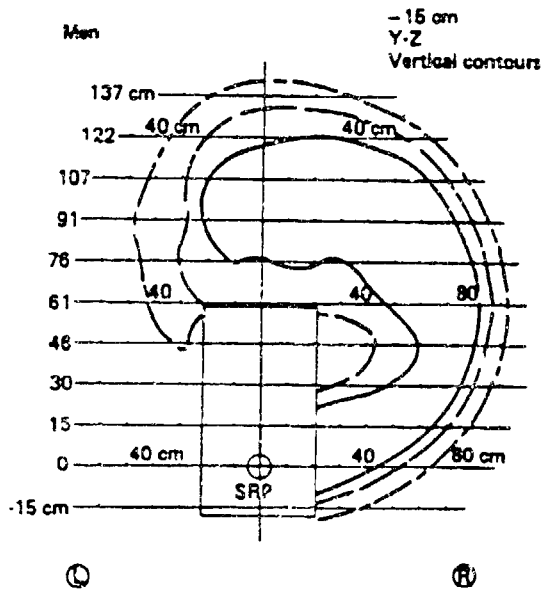
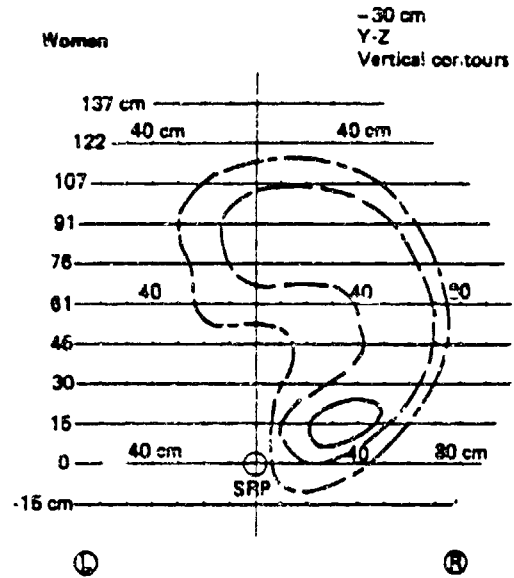
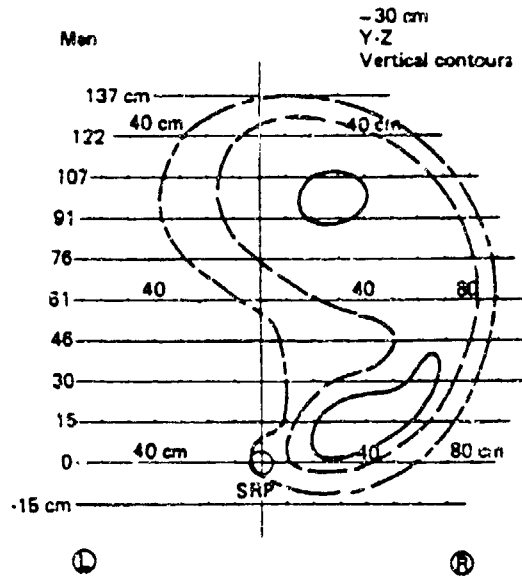
Figure 3.3.3.1-1 Grasp Reach Limits With Right Hand for American Male
Female Populations (Continued)

YZ Plane

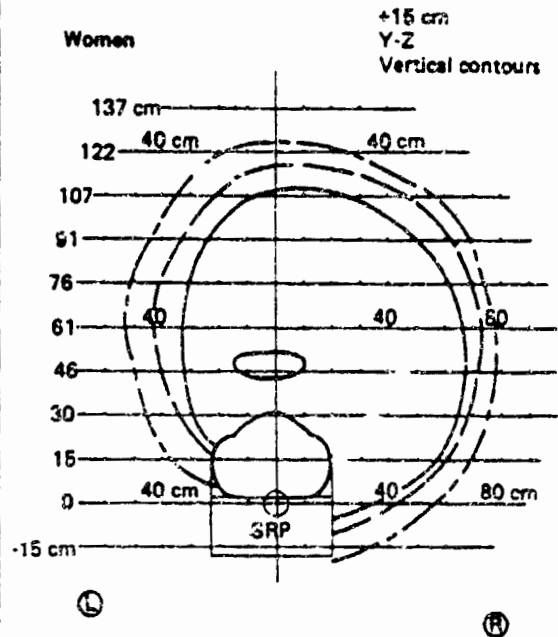
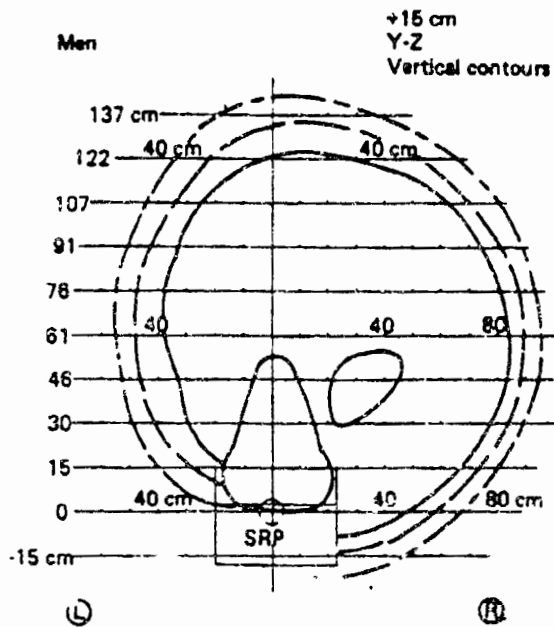
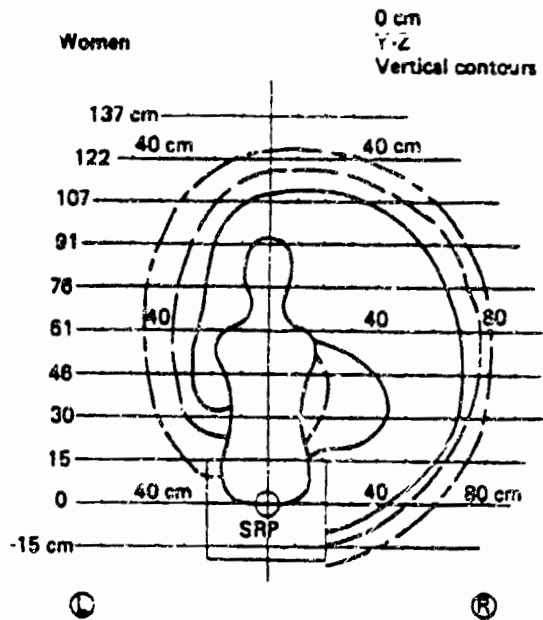
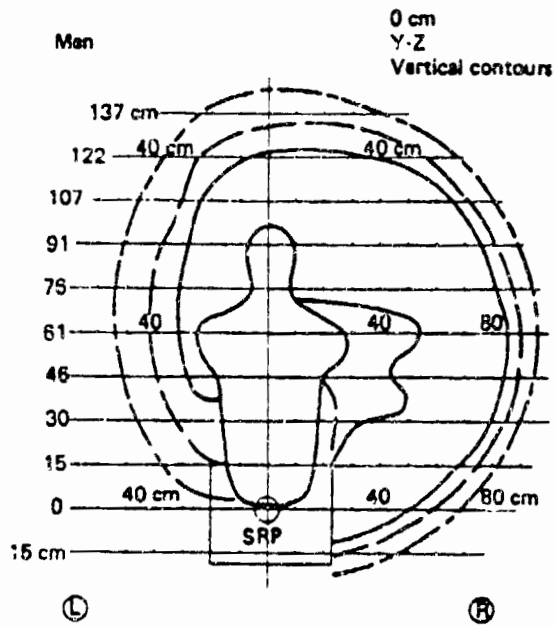


D

Y Z Plane

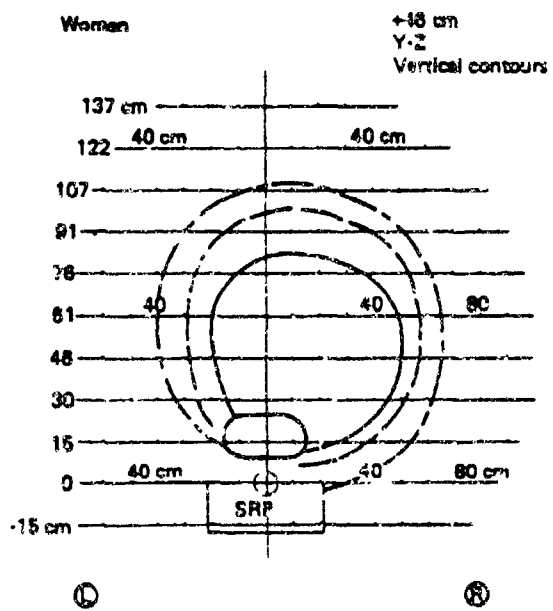
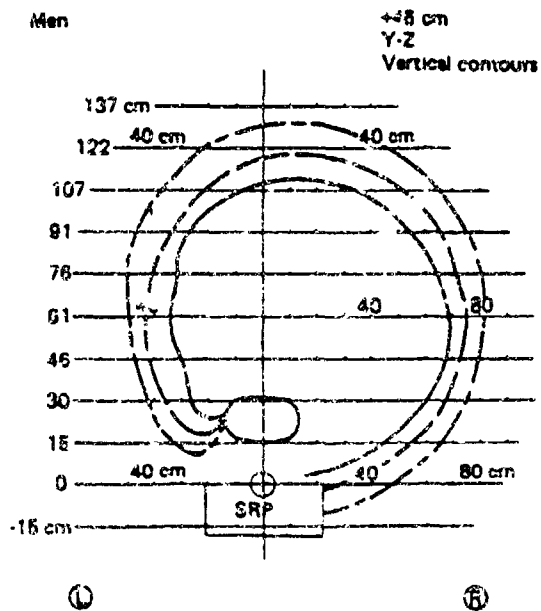
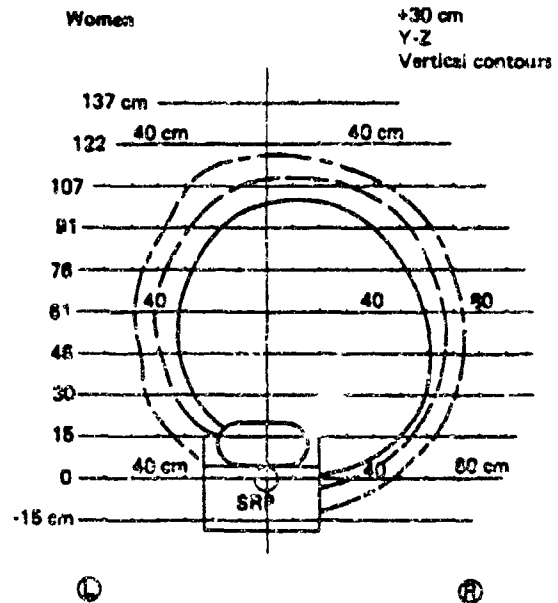
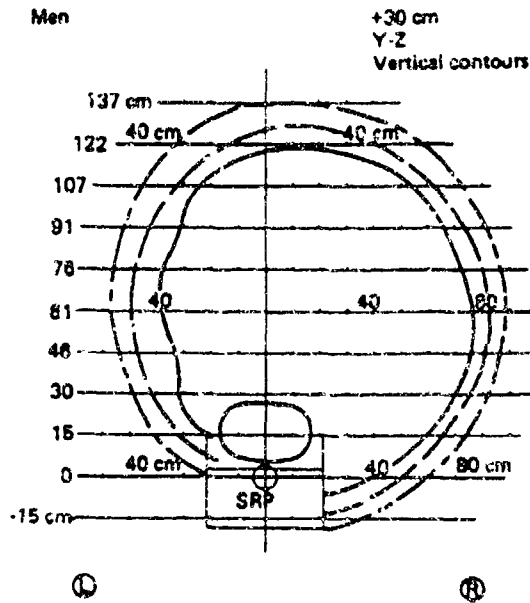


Y Z Plane



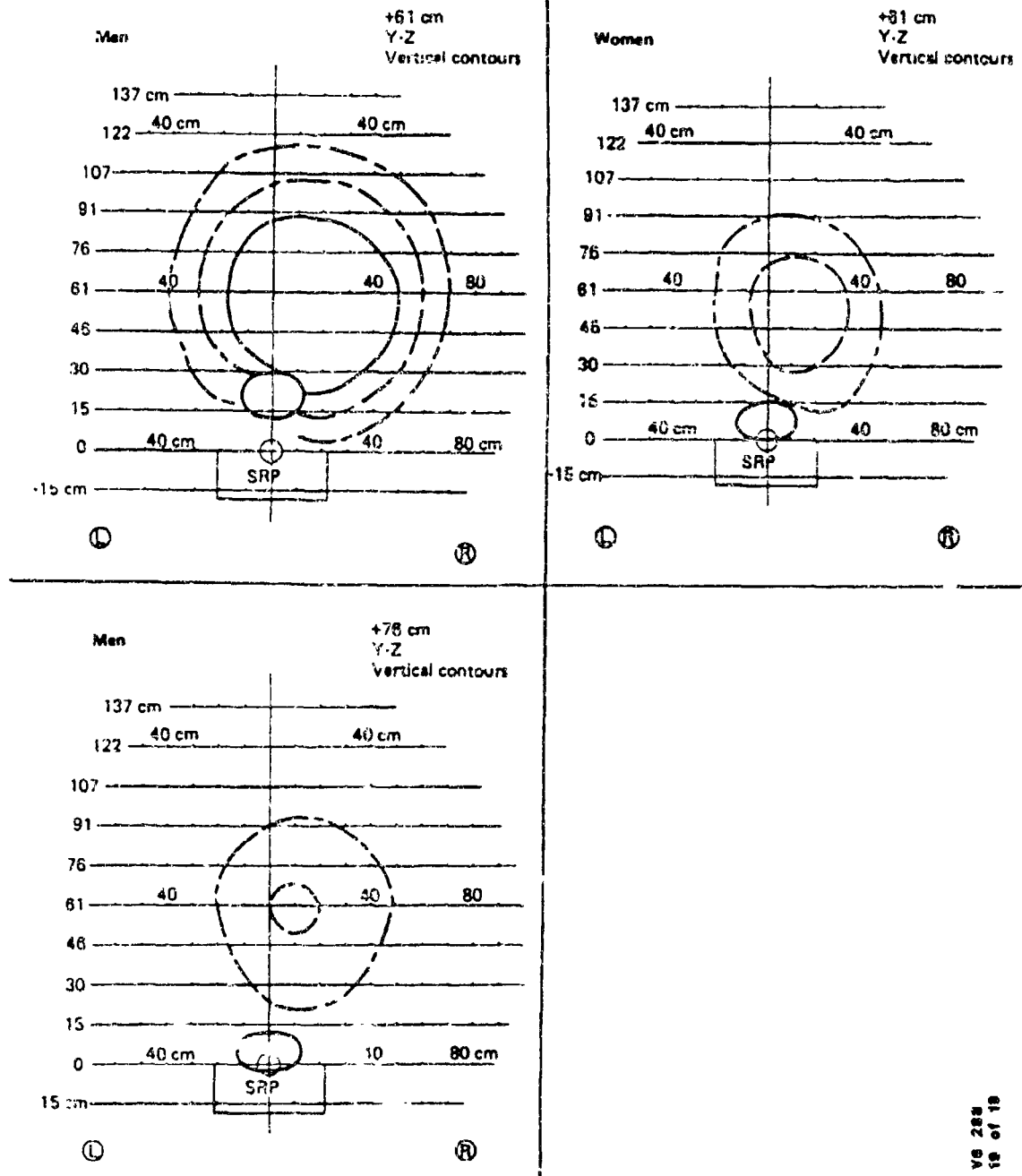
Y6 288
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Y Z Plane



Y0 288
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Y Z Plane



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Direction of arm reach (from 0 deg or "straight ahead," to 90 deg to the right) (deg)	Approximate changes in reach for each single degree of change in backrest angle (reach increases as backrest angle moves to vertical, and vice versa)
0	± 1.02 cm (± 0.40 in)
15	± 1.27 cm (± 0.50 in)
30	± 1.14 cm (± 0.45 in)
45	± 0.94 cm (± 0.37 in)
60	± 0.86 cm (± 0.28 in)
75	± 0.38 cm (± 0.14 in)
90	± 0.25 cm (± 0.10 in)

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Reference: 16, Volume 1, page V-61

**Figure 3.3.3.1-2. Changes in Arm Reach Boundaries as
a Function of Variation in Backrest
Angle of 15 Degrees From Vertical**

Type of task	Adjustment
Finger tip operation	+7.0 cm (2.8 in)
Full hand grasp	-5.5 cm (2.2 in)

Reference: 310 pg 84

**Figure 3.3.3.1-3 Adjustment In Thumb and
Forefinger Grasp Reach Boundaries
for Other Types of Grasping Tasks**

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3.3.5 Body Surface Area

3.3.5.1 Introduction - N/A

3.3.5.2 Body Surface Area Design Considerations - N/A

3.3.5.3 Body Surface Area Data Design Requirements

See Figure 3.3.5.3-1.

3.3.6 Body Volume

3.3.6.1 Introduction - N/A

3.3.6.2 Body Volume Data Design Considerations - N/A

3.3.6.3 Body Volume Data Design Requirements

The data in this section shall be used as appropriate to achieve effective integration of the crew and the Assured Crew Return Vehicle. Body volumes for the crewmember population are given in Figure 3.3.6.3-1 and 3.3.6.3-2.

3.3.7 Body Mass Properties - N/A

3.3.7.1 Introduction - N/A

3.3.7.2 Body Mass Properties Design Considerations - N/A

3.3.7.3 Body Mass Properties Data Design Requirements

The data in this section shall be used as appropriate to achieve effective integration of the crew and space systems.

3.3.7.3.1 Body Mass Data Design Requirements

3.3.7.3.1.1 Whole-Body Mass Data Design Requirements

Whole body mass data for the crewmember population in 1-g is in Figure 3.3.7.3.1.1-1.

3.3.7.3.1.2 Body Segment Mass Data Design Requirements

Body segment mass data for the American male crewmember in 1-g is in Figure 3.3.7.3.1.2-1.

3.3.7.3.2 Center of Mass Data Design Requirements

3.3.7.3.2.1 Whole-Body Center of Mass Data Design Requirements

The whole-body center of mass location data for the American male crewmember in 1-g is in Figure 3.3.7.3.2.1-1. Equations for locating the whole-body center of mass in males of different sizes are given in Figure 3.3.7.3.2.1-2.

3.3.7.3.2.2 Body Segments Center of Mass Data Design Requirements

Center of mass of body location data for body segments of the American male crewmember in 1-g is in Figure 3.3.7.3.2.2-1.

3.3.7.3.3 Moment of Inertia Data Design Requirements

3.3.7.3.3.1 Whole-Body Moment of Inertia Data Design Requirements

Whole-body moments of inertia data for the American male crewmember in 1-g is in Figure 3.3.7.3.3.1-1.

3.3.7.3.3.2 Body Segments Moment of Inertia Data Design Requirements

Body segment moments of inertia data for the American male crewmember in 1-g is in Figure 3.3.7.3.3.2-1.

	American male crewmember body surface area
5th Percentile	17,600 cm ² (2730 in ²)
50th Percentile	20,190 cm ² (3130 in ²)
95th Percentile	22,690 cm ² (3520 in ²)

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Reference: 272, page 1

Notes:

- a. American male crewmember population is defined in paragraph 3.2.1, Anthropometric Database Design Considerations.
- b. Data apply to 1-G conditions.

*Figure 3.3.5.3-1 Estimated Body Surface Area
of the American Male Crewmember*

	American male crewmember body volume
5th Percentile	68,640 cm ³ (4190 in ³)
50th Percentile	85,310 cm ³ (5210 in ³)
95th Percentile	101,840 cm ³ (6210 in ³)

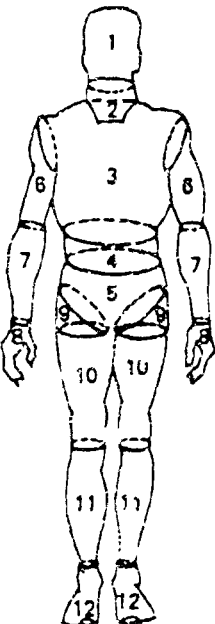
VB 283

Reference: 276, pages 80, 81

Note:

- a. These data apply to 1-G conditions only.
- b. American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations.

*Figure 3.3.6.3-1 Whole Body Volume of American
Male Crewmember*

	Segment	Volume, cm ³ (in ³)		
		5th percentile	50th percentile	95th percentile
	1 Head	4260 (260)	4400 (270)	4550 (280)
	2 Neck	930 (80)	1100 (70)	1270 (80)
	3 Thorax	20420 (1250)	26110 (1590)	31760 (1940)
	4 Abdomen	2030 (120)	2500 (150)	2960 (180)
	5 Pelvis	9420 (570)	12300 (750)	15150 (920)
	6 Upper arm*	1600 (100)	2050 (130)	2500 (150)
	7 Forearm*	1160 (70)	1450 (90)	1720 (100)
	8 Hand	460 (30)	530 (30)	610 (40)
	9 Hip flap*	2890 (180)	3640 (220)	4380 (270)
	10 Thigh minus flap*	5480 (330)	6700 (410)	7920 (480)
	11 Calf*	3320 (200)	4040 (250)	4760 (290)
	12 Foot*	840 (50)	1010 (60)	1180 (70)
	5 + 4 + 3 Torso	31870 (1940)	40910 (2450)	49870 (3040)
	9 + 10 Thigh*	8360 (510)	10340 (630)	12300 (750)
	7 + 8 Forearm plus hand*	1640 (100)	1980 (120)	2320 (140)

Reference: 276, pages 32-79

Notes:

* Average of right and left sides

a. These data apply to 1-G conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

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Figure 3.3.6.3-2 Body Segments Volume of the American Male Crewmember

Whole body mass of year 2000 crewmember population (age 40)

Male (American)			Female (Japanese)		
5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile
65.8 kg (145.1 lb)	82.2 kg (181.3 lb)	98.5 kg (217.2 lb)	41.0 kg (90.4 lb)	51.5 kg (113.5 lb)	61.7 kg (136.0 lb)

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Reference: 16, pages III-92, III-85
308

Notes:

- These data apply to 1-G conditions only. Fluid losses in microgravity reduce these masses.
- Year-2000 crewmember population is defined in paragraph 3.2.1, Anthropometric Database Design Considerations

Figure 3.3.7.3.1.1-1 Whole Body Mass for Year 2000 Crewmember Population

	Segment	Mass, gm (oz, weight)		
		5th percentile	50th percentile	95th percentile
	1 Head	4280 (150)	4400 (160)	4550 (160)
	2 Neck	930 (30)	1100 (40)	1270 (40)
	3 Thorax	20420 (720)	26110 (920)	31760 (1120)
	4 Abdomen	2030 (70)	2500 (90)	2960 (100)
	5 Pelvis	9420 (330)	12300 (430)	15150 (530)
	6 Upper arm*	1600 (60)	2060 (70)	2500 (90)
	7 Forearm*	1180 (40)	1450 (50)	1720 (60)
	8 Hand	460 (20)	530 (20)	610 (20)
	9 Hip flap*	2890 (100)	3640 (130)	4380 (150)
	10 Thigh minus flap*	5480 (190)	6700 (240)	7920 (280)
	11 Calf*	3320 (120)	4040 (140)	4760 (170)
	12 Foot*	840 (30)	1010 (40)	1180 (40)
	5 + 4 + 3 Torso	31870 (1120)	40910 (1440)	49870 (1760)
	9 + 10 Thigh*	8360 (290)	10340 (360)	12300 (430)
	7 + 8 Forearm plus hand*	1640 (60)	1980 (70)	2320 (80)

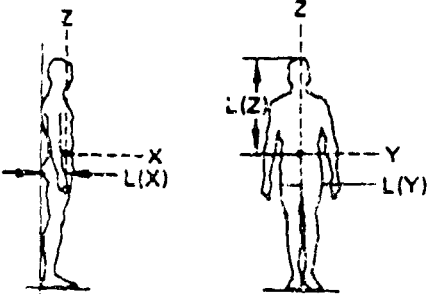
V6 280

Reference: 276, pages 32-79 With Updates

Notes:

- a. These data apply to 1-G conditions.
- b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations.
- * Average of right and left sides

Figure 3.3.7.3.1.2-1. Mass of Body Segments for the American Male Crewmember

Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 <p>$L(Y) = 1/2$ distance between anterior superior iliac spine landmarks (1/2 bispinuous breadth)</p> <p>1. Standing</p> <p>2. Standing, Arms Over Head</p>	L(X)	8.8 (3.4)	9.1 (3.6)	9.6 (3.8)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	75.7 (29.8)	80.2 (31.6)	84.7 (33.3)
	L(X)	8.7 (3.4)	9.0 (3.6)	9.4 (3.7)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	69.9 (27.5)	73.9 (29.1)	77.9 (30.7)

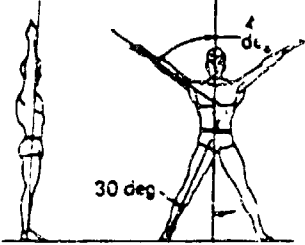
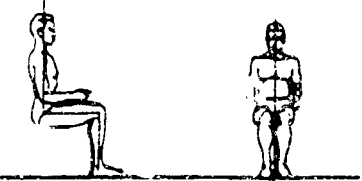
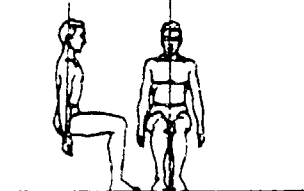
Reference: 16, Chapter IV
260

Notes:

- These data apply to 1-G conditions. To estimate center of mass location in microgravity, multiply the L(z) figure by 0.9.
- The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

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Figure 3.3.7.3.2.1-1. Whole Body Center of Mass Location of the American Male Crewmember

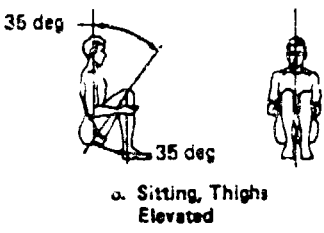
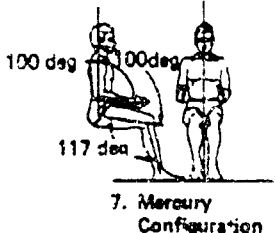
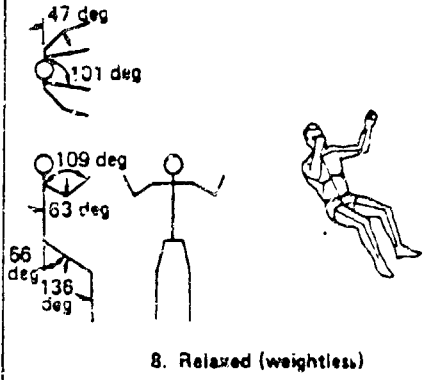
Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 <p>3. Spread Eagle</p>	L(X)	8.2 (3.2)	8.6 (3.4)	9.0 (3.6)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	69.4 (27.3)	73.5 (28.9)	77.5 (30.5)
 <p>4. Sitting</p>	L(X)	19.4 (7.7)	20.8 (8.1)	21.2 (8.6)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	65.2 (25.7)	68.8 (27.0)	71.9 (28.3)
 <p>5. Sitting, Forearms Down</p>	L(X)	18.9 (7.4)	20.0 (7.9)	21.1 (8.3)
	L(Y)	11.7 (4.8)	12.5 (4.9)	13.3 (5.2)
	L(Z)	66.0 (26.0)	69.3 (27.3)	72.5 (28.6)

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250

Notes:

- a. These data apply to 1-G conditions. To estimate center of mass location in microgravity, multiply the L(z) figure by 0.9
 b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

Figure 3.3.7.3.2.1-1. Whole Body Center of Mass Location of the American Male Crewmember (Continued)

Whole body center of mass for the American male crewmember (1 gravity only) cm (in)				
	Dimension	5th percentile	50th percentile	95th percentile
 <p>a. Sitting, Thighs Elevated</p>	L(X)	17.6 (6.9)	18.8 (7.4)	20.1 (7.9)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	57.3 (22.5)	59.4 (23.4)	61.5 (24.2)
 <p>7. Mercury Configuration</p>	L(X)	19.4 (7.6)	20.5 (8.1)	21.5 (8.5)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	66.8 (26.3)	69.9 (27.5)	73.0 (28.7)
 <p>8. Relaxed (weightless)</p>	L(X)	18.0 (7.1)	18.8 (7.4)	19.8 (7.7)
	L(Y)	11.7 (4.6)	12.5 (4.9)	13.3 (5.2)
	L(Z)	68.0 (26.8)	70.9 (27.9)	73.7 (29.0)

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3 of 3Reference: 16, Chapter IV
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Notes.

- a. These data apply to 1-G conditions. To estimate center of mass location in microgravity, multiply the L(z) figure by 0.9.
- b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

Figure 3.3.7.3.2.1-1. Whole Body Center of Mass Location of the American Male Crewmember (Continued)

Location of
center of

$$\text{mass, cm} = \{A \times (\text{stature, cm})\} + \{B \times (\text{weight, lbs})\} + \{C\}$$

Posture	Dimension	A	B	C	SE *(cm)	R**
1. Standing	L (X)	-0.035	0.024	11.008	0.33	0.7636
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.486	-0.014	-4.775	1.33	0.9329
2. Standing (arms over head)	L (X)	-0.040	0.020	12.832	0.45	0.5823
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.416	-0.007	0.305	1.52	0.8927
3. Spread eagle	L (X)	-0.031	0.020	10.443	0.38	0.6706
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.392	0.002	2.547	1.48	0.8921
4. Sitting	L (X)	0.080	0.010	4.150	0.56	0.7900
	L (Y)	0	0.021	8.608	0.89	0.4310
	L (Z)	0.344	-0.004	7.327	1.46	0.8632
5. Sitting (thighs elevated)	L (X)	0.041	0.022	7.405	0.68	0.7104
	L (Y)	0	0.021	8.610	0.89	0.4310
	L (Z)	0.212	-0.002	21.582	1.24	0.7801
6. Sitting (with arms down)	L (X)	0.075	0.010	4.628	0.51	0.8030
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.355	-0.010	7.389	1.53	0.8469
7. Mercury configuration	L (X)	0.076	0.008	6.257	0.54	0.7828
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.311	-0.002	14.425	1.80	0.7841
8. Weightless	L (X)	0.077	0.001	4.692	0.60	0.6973
	L (Y)	0	0.021	8.609	0.89	0.4310
	L (Z)	0.218	0.017	28.552	3.18	0.5015

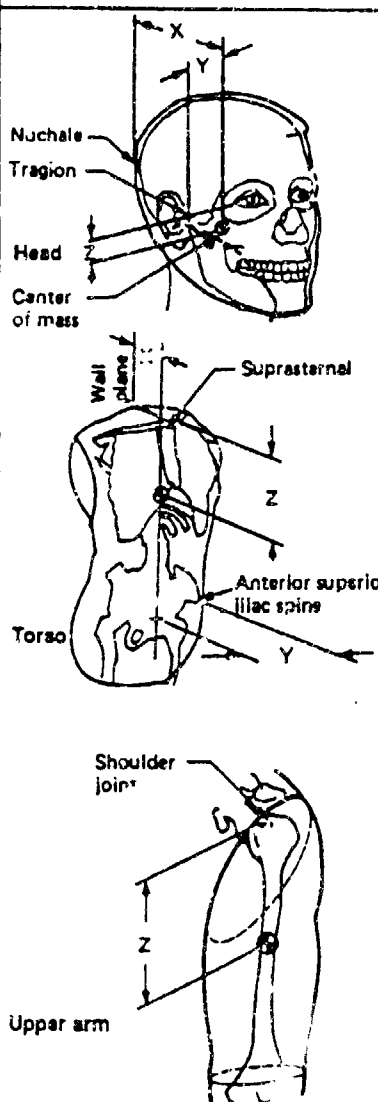
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Reference: 250

Notes:

- Refer to Figure 3.3.7.3.2.1-1 for measurement landmarks
- * SE = Standard error of the estimate
- ** R = Multiple correlation coefficient
- These data apply only to 1-g conditions. To estimate center of mass location in microgravity, multiply the L(z) figure by 0.9.
- The American male crewmember population is defined in paragraph 3.2.1, Anthropometric Database Design Considerations
- A = is a dimensionless constant for a given posture that relates center of mass location to stature
- B = is a constant for a given posture that has the dimensions of cm divided by lbs and relates center of mass location to body weight
- C = a constant in cm for a given posture to assist in determining the location of the center of mass

Figure 3.3.7.3.2.1-2 Whole Body Center of Mass Location for American Male Crewmembers of Different Sizes

Center of mass location, cm (in)									
	5th percentile			50th percentile			95th percentile		
	X	Y	Z	X	Y	Z	X	Y	Z
Head	9.4 (3.7)	6.8 (2.7)	2.1 (0.8)	10.4 (4.1)	7.2 (2.8)	2.3 (0.9)	11.5 (4.5)	7.7 (3.0)	2.5 (1.0)
Torso	8.4 (3.3)	13.8 (5.4)	21.0 (8.3)	10.0 (3.9)	15.8 (6.2)	21.8 (8.6)	11.6 (4.6)	17.8 (7.0)	22.6 (8.9)
Upper arm	*	*	14.1 (5.5)	*	*	14.9 (5.9)	*	*	15.7 (6.2)

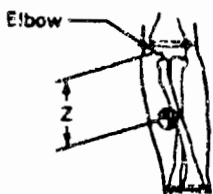
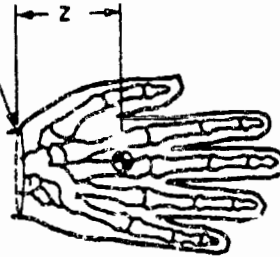
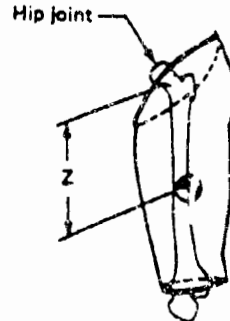
Reference: 16, Chapter IV

Notes:

- These data apply to 1 condition only.
 - The American male crew member population is defined in Paragraph 3.2.1 Anthropometric Database Design Considerations
- * Assume symmetry

Figure 3.3.7.3.2.2-1 Body Segment of Mass for American Male Crewmember

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Center of mass location, cm (in)									
	5th percentile			50th percentile			95th percentile		
	X	Y	Z	X	Y	Z	X	Y	Z
 Elbow Forearm	*	*	11.5 (4.5)	*	*	11.5 (4.5)	*	*	12.1 (4.8)
 Wrist Hand	*	*	5.1 (2.0)	*	*	5.6 (2.2)	*	*	6.0 (2.4)
 Hip joint Thigh	*	*	17.0 (6.7)	*	*	18.0 (7.1)	*	*	19.1 (7.5)

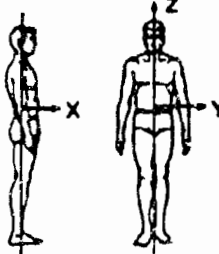
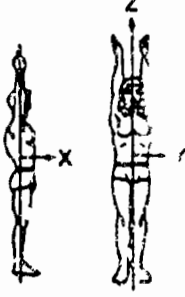
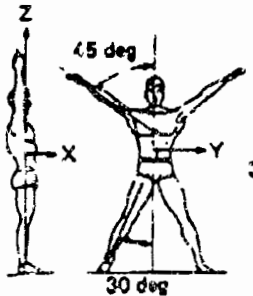
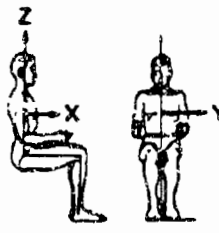
Reference: 16, Chapter IV

* Assume symmetry

Notes:

- These data apply to 1-G conditions only.
 - The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database.
- * Assume symmetry

Figure 3.3.7.3.2.2-1 Body Segment of Mass for American Male Crewmember (Continued)

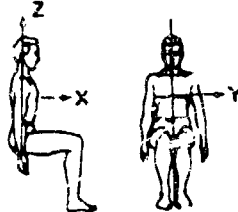
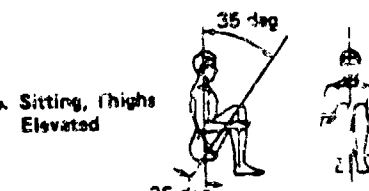
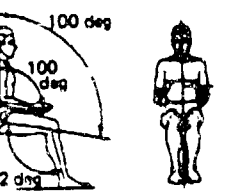
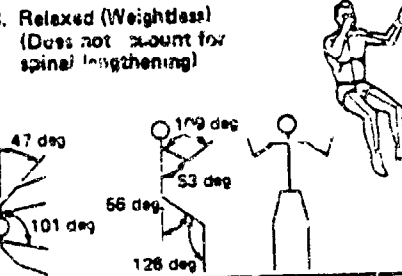
Moment of Inertia, $\text{g-cm}^2 \times 10^6$ (lb-in-sec ²)				
Posture	Axis	5th percentile	50th percentile	95 percentile
 1. Standing	X	106.5 (94.2)	144.5 (101.3)	182.3 (161.2)
	Y	94.9 (83.9)	129.2 (114.3)	163.4 (144.5)
	Z	10.3 (9.1)	14.4 (12.7)	18.5 (16.4)
 2. Standing, Arms Over Head	X	110.0 (124.7)	191.9 (169.7)	242.6 (214.6)
	Y	121.5 (110.2)	172.9 (152.9)	221.0 (195.5)
	Z	10.8 (9.4)	14.1 (12.5)	17.5 (15.5)
 3. Spread Arms	X	137.2 (121.3)	190.4 (168.4)	243.4 (215.3)
	Y	104.2 (92.2)	144.8 (128.1)	185.2 (163.8)
	Z	32.0 (28.3)	46.6 (41.2)	61.3 (54.2)
 4. Sitting	X	67.3 (50.7)	76.9 (62.0)	96.5 (85.3)
	Y	62.0 (54.8)	83.2 (73.8)	104.3 (92.2)
	Z	30.7 (27.2)	42.4 (37.3)	54.0 (47.8)

Reference: 16, IV-42, IV-25

Notes:

- a. These data apply to 1-G conditions only.
 b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations.

Figure 3.3.7.3.3.1-i. Whole Body Moment of Inertia for the American Male Crewmember

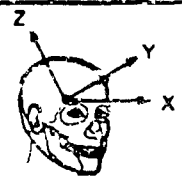
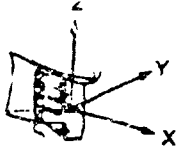
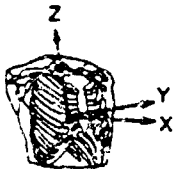
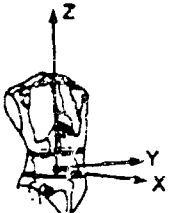
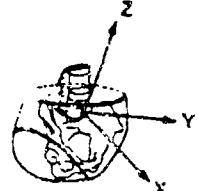
Moment of inertia, $\text{g-cm}^2 \times 10^6$, (lb-in-sec ²)				
Posture	Axis	5th percentile	50th percentile	95 percentile
 <p>5. Sitting, Forearms Down</p>	X	59.2 (52.4)	77.8 (68.6)	96.0 (84.9)
	Y	63.9 (56.1)	86.3 (76.3)	108.6 (96.0)
	Z	30.9 (27.3)	42.8 (37.9)	54.6 (43.3)
 <p>6. Sitting, Thighs Elevated</p>	X	37.6 (33.3)	48.7 (43.1)	59.8 (52.9)
	Y	37.2 (32.9)	41.0 (41.2)	50.0 (49.3)
	Z	23.9 (21.1)	33.7 (29.5)	43.0 (38.5)
 <p>7. Mercury Configuration</p>	X	32.5 (55.0)	62.2 (72.7)	101.8 (90.0)
	Y	31.6 (61.6)	95.5 (84.5)	121.3 (107.3)
	Z	31.9 (28.2)	43.0 (38.0)	54.0 (47.8)
 <p>8. Relaxed (Weightless) (Does not account for spinal lengthening)</p>	X	89.0 (77.8)	114.5 (100.3)	140.9 (124.5)
	Y	84.1 (74.4)	109.8 (93.9)	134.8 (119.2)
	Z	33.8 (35.2)	50.5 (44.7)	61.2 (54.1)

Reference: 16, IV-42, 1-25

Notes:

- These data apply to 1-G conditions only
- The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

Figure 3.3.7 3.3.1-1. Whole Body Moment of Inertia for the American Male Crewmember (Continued)

Moment of Inertia, $\text{g-cm}^2 \times 10^3$, ($\text{lb-in-sec}^2 \times 10^3$)				
Segment	Axis	5th Percentile	50th Percentile	95th Percentile
Head 	X	185.2 (172.7)	207.1 (183.2)	213.9 (193.3)
	Y	221.8 (196.2)	235.8 (209.4)	251.6 (222.5)
	Z	144.9 (128.1)	153.2 (135.5)	161.4 (142.7)
Neck 	X	13.4 (11.9)	18.2 (16.1)	23.0 (20.3)
	Y	18.6 (14.7)	22.0 (19.5)	27.4 (24.2)
	Z	20.3 (17.9)	27.5 (24.3)	34.6 (30.3)
Thorax 	X	3509.6 (3103.9)	5312.0 (4697.9)	7100.2 (6273.4)
	Y	2558.3 (2280.8)	3920.6 (3487.4)	5274.0 (4664.3)
	Z	2153.8 (1904.8)	3320.1 (2936.0)	4475.5 (3958.1)
Abdomen 	X	116.6 (103.1)	175.2 (155.0)	233.2 (206.2)
	Y	63.3 (56.0)	98.2 (86.8)	132.6 (117.3)
	Z	173.8 (153.5)	265.4 (234.7)	356.1 (315.0)
Pelvis 	X	710.0 (631.2)	1123.4 (983.6)	1528.9 (1352.1)
	Y	648.4 (571.7)	1053.5 (914.0)	1418.4 (1252.7)
	Z	820.0 (752.2)	1300.0 (1152.9)	1782.0 (1575.0)

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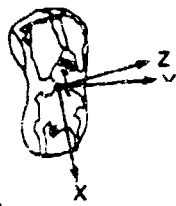


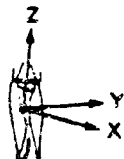

Reference: 276, pages 22-79

Notes:

a. These data apply to 1-G conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Con.

Figure 3.3.7.3.3.2-1 Body Segment Moment of Inertia for the American Male Crewmember

Moment of Inertia, $\text{g-cm}^2 \times 10^3$, (lb-in-sec ² $\times 10^3$)				
Segment	Axis	5th Percentile	50th Percentile	95th Percentile
Torso 	X	10731.4 (9490.9)	15957.8 (14113.0)	21141.0 (18697.1)
	Y	1556.3 (2280.8)	3920.8 (3487.4)	5274.0 (4364.3)
	Z	2153.6 (19004.8)	3320.1 (2936.3)	5274.0 (4664.3)
Right upper arm 	X	92.6 (81.9)	141.7 (125.4)	190.5 (168.6)
	Y	97.6 (88.3)	151.2 (133.7)	204.4 (180.8)
	Z	18.5 (15.3)	29.2 (25.8)	39.8 (35.2)
Left upper arm 	X	89.1 (78.8)	137.2 (121.43)	185.0 (163.6)
	Y	93.3 (82.5)	145.7 (128.9)	197.8 (174.9)
	Z	17.8 (15.8)	28.2 (24.9)	38.4 (34.0)
Right forearm 	X	85.3 (57.7)	93.9 (83.1)	122.4 (108.3)
	Y	66.3 (58.6)	95.3 (84.6)	124.8 (110.4)
	Z	9.5 (8.5)	14.2 (12.6)	19.8 (16.6)
Left forearm 	X	63.7 (56.3)	98.9 (78.6)	113.9 (100.7)
	Y	65.4 (57.8)	91.5 (80.9)	117.4 (103.9)
	Z	8.9 (7.9)	12.9 (11.4)	16.9 (14.9)

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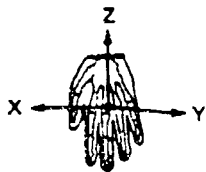

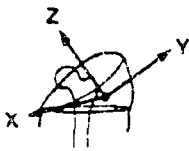
Reference: 276, pages 32-79

Notes:

a. These data apply to 1-g conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Con.

Figure 3.3.7.3.2-1 Body Segment Moment of Inertia for the American Male Crewmember (Continued)

Moment of Inertia, $\text{g-cm}^2 \times 10^3$, (lb-in-sec ² $\times 10^3$)						
Segment	Axis	5th Percentile	50th Percentile	50th Percentile	95th Percentile	95th Percentile
Right Hand 	X	10.7 (9.4)	13.8 (12.2)	16.8 (14.9)		
	Y	9.7 (7.7)	11.2 (9.9)	13.7 (12.1)		
	Z	3.4 (3.0)	4.5 (4.0)	5.5 (4.9)		
Left Hand 	X	10.8 (9.5)	13.6 (12.0)	16.4 (14.5)		
	Y	9.0 (7.9)	11.3 (10.0)	13.8 (12.0)		
	Z	3.5 (3.1)	4.4 (3.9)	5.3 (4.7)		
Right Hip flap 	X	86.2 (78.5)	134.1 (118.6)	178.9 (158.2)		
	Y	116.3 (106.2)	173.1 (153.1)	229.4 (202.9)		
	Z	150.4 (133.1)	226.5 (200.3)	301.7 (256.9)		
Left Hip flap 	X	85.0 (75.1)	126.8 (113.9)	172.2 (152.3)		
	Y	113.4 (100.3)	169.2 (149.7)	224.5 (198.5)		
	Z	146.7 (129.8)	219.2 (193.8)	290.8 (257.2)		

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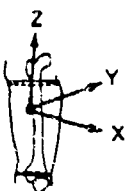

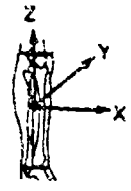
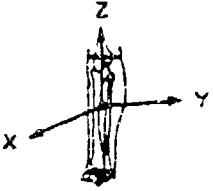
Reference: 276, pages 32-79

Notes:

a. These data apply to 1-G conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Con.

Figure 3.3.7.3.2-1 Body Segment Moment of Inertia for the American Male Crewmember (Continued)

Moment of inertia, $\text{g-cm}^2 \times 10^3$, (lb-in-sec ² $\times 10^3$)					
Segment	Axis	5th Percentile	50th Percentile	95th Percentile	
Right Thigh minus flap 	X	453.8 (401.2)	653.1 (577.8)	852.3 (753.8)	
	Y	489.2 (415.0)	873.4 (595.8)	877.3 (775.9)	
	Z	178.4 (157.8)	255.2 (225.7)	331.3 (293.0)	
Left Thigh minus flap 	X	437.3 (385.8)	620.9 (549.1)	804.0 (711.1)	
	Y	480.7 (407.5)	653.4 (577.9)	845.7 (747.8)	
	Z	172.3 (152.4)	246.9 (218.3)	321.0 (283.8)	
Right Calf 	X	430.7 (381.0)	616.1 (546.8)	804.8 (711.8)	
	Y	437.7 (387.1)	627.1 (554.8)	815.0 (721.7)	
	Z	51.8 (45.8)	72.0 (63.7)	92.1 (81.5)	
Left Calf 	X	434.1 (383.9)	629.6 (556.8)	824.7 (729.4)	
	Y	441.4 (390.3)	639.7 (565.8)	837.7 (740.9)	
	Z	56.7 (44.9)	72.8 (64.4)	94.7 (83.7)	

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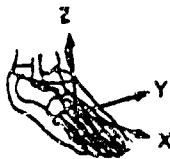
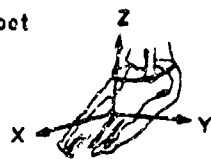
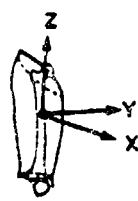
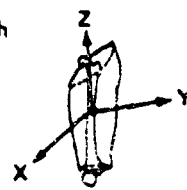
Reference: 275, pages 32-79

Notes:

a. These data apply to 1-G conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations

Figure 3.3.7.3.3.2-1 Body Segment Moment of Inertia for the American Male Crewmember (Continued)

Moment of Inertia, $\text{g-cm}^2 \times 10^3$, ($\text{lb-in}^2 \times 10^3$)					
Segment	Axis	5th Percentile	50th Percentile	95th Percentile	
Right Foot 	X	8.5 (5.7)	8.7 (7.7)	10.9 (9.8)	
	Y	33.8 (29.9)	46.1 (29.9)	58.3 (51.5)	
	Z	38.0 (31.8)	46.8 (31.8)	61.7 (54.5)	
Left Foot 	X	8.1 (5.7)	8.3 (7.4)	10.6 (9.3)	
	Y	32.4 (29.9)	44.7 (39.5)	57.0 (50.4)	
	Z	34.2 (30.2)	47.0 (41.6)	59.8 (52.9)	
Right Thigh 	X	1163.7 (1029.2)	1689.8 (1494.4)	2219.9 (1958.0)	
	Y	1225.4 (1083.8)	1780.9 (1575.0)	2334.2 (2064.4)	
	Z	316.5 (279.9)	464.6 (410.5)	611.3 (540.6)	
Left Thigh 	X	1122.6 (992.6)	1623.0 (1435.4)	2121.1 (1875.9)	
	Y	1186.3 (1049.2)	1713.2 (1515.1)	2237.5 (1978.8)	
	Z	306.2 (270.8)	448.5 (396.6)	589.5 (521.3)	

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Reference: 276, pages 32-79

Notes:

a. These data apply to 1-6 conditions only.

b. The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Con.

Figure 3.3.7.3.3.2-1 Body Segment Moment of Inertia for the American Male Crewmember (Continued)

Moment of Inertia, $\text{g-cm}^2 \times 10^3$, (lb-in-sec ² $\times 10^3$)				
Segment	Axis	5th Percentile	50th Percentile	95th Percentile
Right forearm plus hand 	X	238.5 (210.9)	327.0 (289.8)	418.7 (388.5)
	Y	237.5 (210.0)	326.5 (288.8)	415.1 (387.2)
	Z	13.4 (11.9)	19.2 (17.0)	25.0 (22.1)
Left forearm plus hand 	X	234.1 (207.0)	314.1 (277.8)	293.8 (348.3)
	Y	232.6 (205.9)	312.2 (276.1)	391.2 (346.0)
	Z	12.8 (11.4)	17.9 (15.9)	23.0 (20.3)

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Reference: 276, pages 32-79

Notes:

- These data apply to 1-G conditions only.
- The American male crewmember population is defined in Paragraph 3.2.1, Anthropometric Database Design Considerations.

Figure 3.3.7.3.3.2-1 Body Segment Moment of Inertia for the American Crewmember (Continued).

4.0 HUMAN PERFORMANCE CAPABILITIES

4.1 INTRODUCTION - N/A

4.2 VISION

4.3 AUDITORY SYSTEM

4.4 OLFACTION AND TASTE

4.5 VESTIBULAR SYSTEM

4.6 KINESTHESIA

4.7 REACTION TIME

4.8 MOTOR SKILLS (Coordination)

4.9 STRENGTH

4.9.1 Introduction - N/A

4.9.2 Strength Design Considerations - N/A

4.9.3 Strength Design Requirements

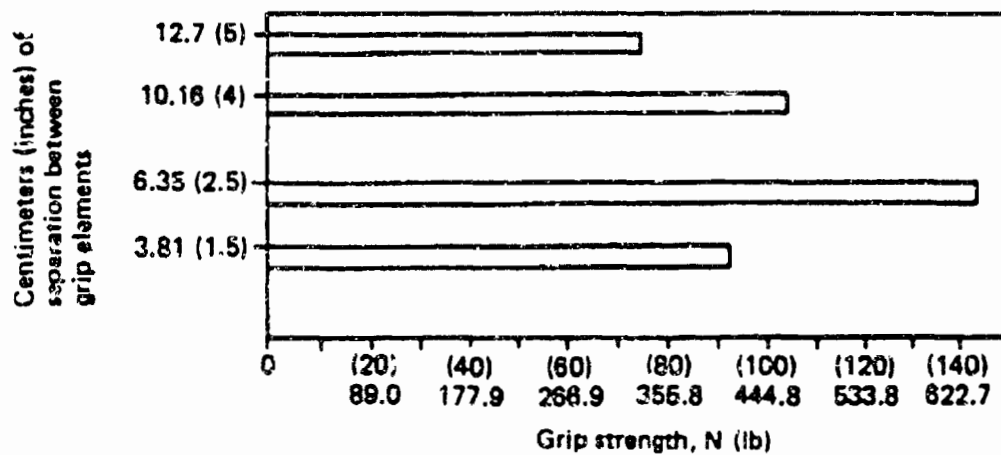
Strength data that shall be used to guide design work are provided below. The deconditioned crewmember as specified in section 4.10 for Effects of Deconditioning shall be accommodated.

a. Grip Force:

1. Grip strength, as a function of the size of the gripped object, is provided for men in Figure 4.9.3-1.
2. Maximum grip strength for men (5th, 50th, and 95th percentile) is given in Figure 4.9.3-2.
3. Grip strength for females is shown in Figure 4.9.3-3.

b. Arm, Hand, and Thumb/Finger Strength - Figure 4.9.3-4 presents arm, hand and thumb/finger strength for fifth percentile males. These figures must be corrected for females (see Figure 4.9.3-5).

c. Male/Female Muscular Strength - Figure 4.9.3-5 provides a comparison of male and female muscular strength for different muscle groups. These data allow a more accurate extrapolation from male to female strength data than is provided by the old method of assuming females have two thirds the strength of men.



Reference: 1, page 2.5-12

Note:

44 subjects, all pilots
or aviation cadets

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Figure 4.9.3-1 Male Grip Strength as a Function of the Separation Between Grip Elements

Population	Percentiles, N (lb)			
	5th	50th or mean	95th	Population S.D.
U.S. Air Force personnel, aircrewmen:				
Right hand	457 (105)	596 (134)	726 (164)	80.1 (18.0)
Left hand	427 (98)	552 (124)	685 (154)	71.2 (15.0)

Reference: 1, page 2.5-18

Figure 4.9.3-2 Grip Strength for Males

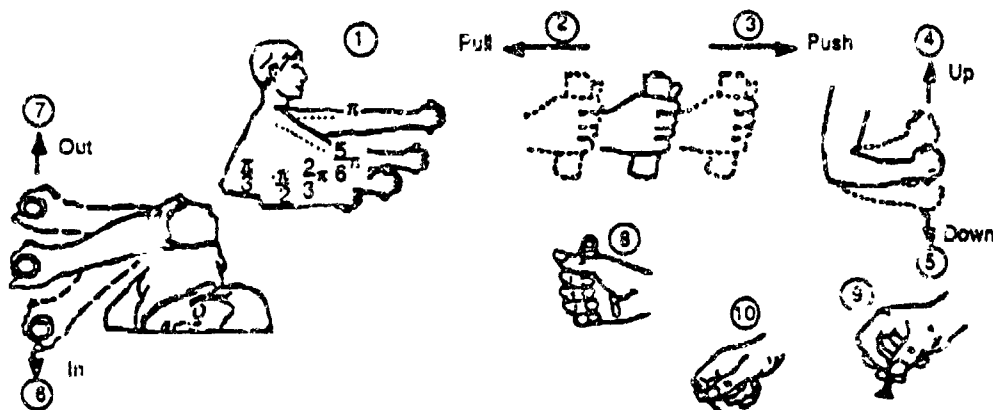
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Population	Percentiles, N (lb)			
	5th	50th	95th	Population S.D.
U. S. Navy personnel				
Mean of both hands	258 (58)	325 (73)	387 (87)	39.1 (8.8)
U. S. Industrial workers:				
Preferred hand	254 (57)	329 (74)	405 (91)	45.8 (10.3)

Reference: 1, page 2.5-18

Figure 4.9.3-3 Grip Strength for Females

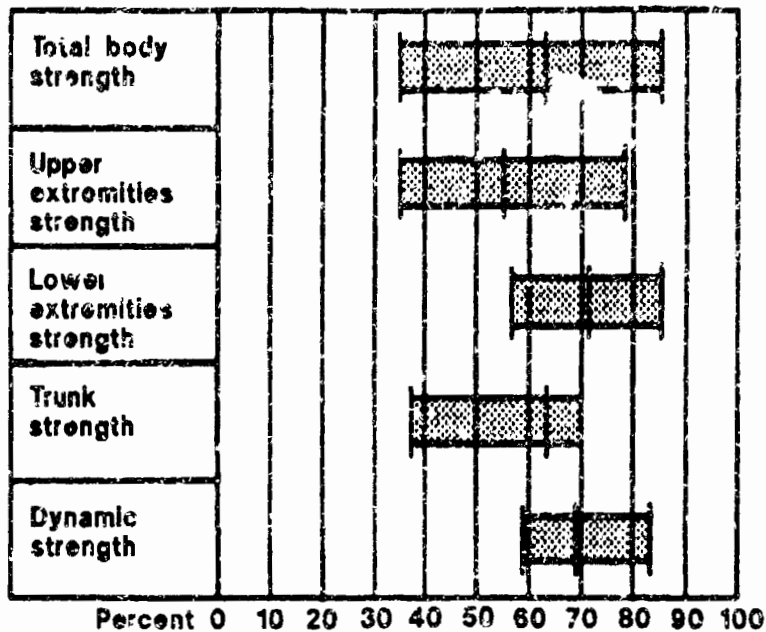
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Arm strength (N)												
(1) Degree of elbow flexion (rad)	(2)		(3)		(4)		(5)		(6)		(7)	
	Pull		Push		Up		Down		In		Out	
	L*	R*	L	R	L	R	L	R	L	R	L	R
π	222	231	187	222	40	82	58	76	56	89	36	62
$5/6 \pi$	187	249	133	187	67	80	80	89	67	89	36	57
$2/3 \pi$	151	187	116	160	76	107	93	116	89	94	45	67
$1/2 \pi$	142	165	98	160	76	89	93	116	71	80	45	71
$1/3 \pi$	116	107	96	151	67	89	80	89	76	80	53	76
Hand and thumb-finger strength (N)												
	(8)		(9)		(10)							
	Hand grip		Thumb-finger grip (Palmer)		Thumb-finger grip (tips)							
	L	R	L	R	L	R						
Momentary hold	250		260		60							
Sustained hold	145		155		35							
* Elbow angle shown in radians * L = Left; R = Right												
Arm strength (lb)												
(1) Degree of elbow flexion (deg)	(2)		(3)		(4)		(5)		(6)		(7)	
	Pull		Push		Up		Down		In		Out	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	57	42	50	9	14	13	1	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18	10	16
60	26	24	22	34	15	20	18	20	17	20	12	17
Hand and thumb-finger strength (lb)												
	(8)		(9)		(10)							
	Hand grip		Thumb-finger grip (Palmer)		Thumb-finger grip (tips)							
	L	R	L	R	L	R						
Momentary hold	56		59		13							
Sustained hold	33		35		8							
* Left; R = Right												

Reference: 2, page 113

Figure 4.9.3-4 Arm, Hand and Thumb/Finger Strength (5th Percentile Male Data)



Reference: 1E, page VII-50

Note:

Female strength as a percentage of male strength for different conditions. The vertical line within each shaded bar indicates the mean percentage difference. The end points of the shaded bars indicate the range.

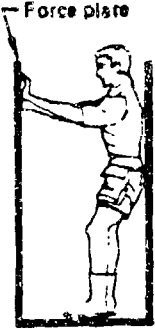
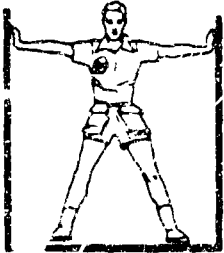
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Figure 4.9.3-5 Comparison of Female vs. Male Muscular Strength

d. Static Push Force - Maximal static push forces for adult males are shown in Figure 4.9.3-6. While these data were collected in a 1-G situation, the fact that they do not depend on friction resulting from body weight makes them applicable to microgravity. Corrections will have to be made for females (see Figure 4.9.3-5).

e. Leg Strength - Leg strength for the 5th percentile male as a function of various thigh and knee angles is reported in Figure 4.9.3-7. Estimates of female leg strength can be made from these data using the correction factors provided in Figure 4.9.3-5.

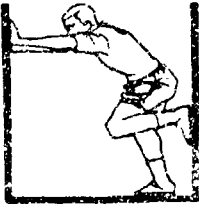
f. Torque Strength - Maximum hand torque data are provided in Figure 4.9.3-8.

	Force-plate (1) height	Distances (2)	Force, N (lbf)	
			Means	SD
	100 percent of shoulder height	50	Both hands	
		60		
		70		
		80		
		90		
		100		
		50	Preferred hand	
		60		
		70		
		80		
		90		
		100		
	100 percent of shoulder height	50	369 (83)	138 (31)
		60	347 (78)	125 (28)
		70	520 (117)	165 (37)
		80	707 (159)	191 (32)
		90	325 (73)	133 (30)
		Percent of span **		

Reference: 1, page 2.5-5, -6

Figure 4.9.3-6 Maximal Static Push Forces

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	Force-plate (1) height	Distances (2)	Force, N (lb)	
			Means	SD
	30	100	774 (174)	214 (48)
	50	120	778 (175)	151 (37)
	70	120	818 (184)	158 (35)
	Percent of shoulder height		1-g applicable data	

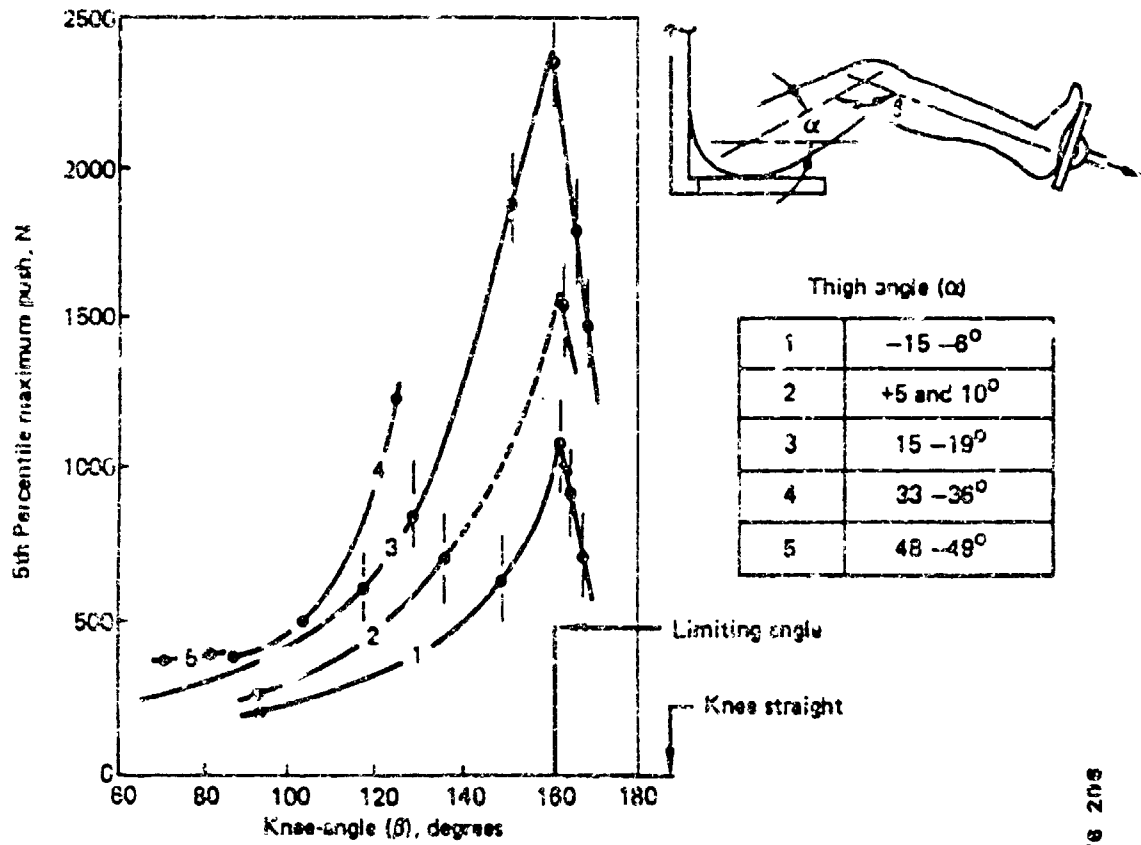
Reference 1, page 25-5, -9

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Notes:

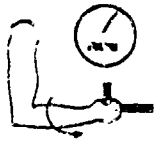

- (1) Height of the center of the force plate - 200 mm (8 in.) high by 254 mm (10 in.) long - upon which force is applied.
 - (2) Horizontal distance between the vertical surface of the force plate and the opposing vertical surface (wall or footrest, respectively) against which the subject brace themselves.
 - Thumb-tip reach - distance from backrest to tip of subject's thumb as thumb and fingertips are pressed together.
 - ** Span - the maximal distance between a person's fingertips as he extends his arms and hands to each side.
- (3) 1-g data

Figure 4.9.3-6 Maximal Static Push Forces (Continued)



Reference: 2, page 115

Figure 4.9.3-7. Leg Strength at Various Knee and Thigh Angles (5th Percentile Male Data)

	Unpressurized suit, bare handed	
	Mean	SD
 Maximum torque: Supination, Nm (lb-in.)	13.73 (121.5)	3.41 (30.1)
 Maximum torque: Pronation, Nm (lb-in.)	17.39 (153.9)	5.08 (45.0)

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Reference: 1, page 2.5-2C

Figure 4.9.3-8 Torque Strength

4.10 Effects of Deconditioning

Figure 4.10-1 presents design requirements and constraints for accommodating deconditioned crewmembers. In establishing these requirements, different levels of conservatism were applied to normal, and to backup/contingency activities. Activities normally required for safe return must assure success for highly deconditioned crews. Activities associated with off-nominal, low probability situations are based on more optimistic estimates of crew capability. In applying these requirements, the following must be observed:

- a. Crew activities and implementation methods listed are not presented as requirements, but as a catalog of candidates for which the crew may be used if the associated requirements and constraints are met. If activities or implementation methods not listed herein are intended, they must be submitted to the ACRV Project Office for approval and subsequent incorporation into this document.
- b. For design purposes, deconditioning effects are assumed significant only during reentry and subsequent mission phases. For operations prior to entry interface (0.2g), other sections of this document are to be applied without derating for deconditioning.
- c. All crewmembers will remain in their couches, appropriately restrained, throughout reentry and landing. After landing, the crew will not be required to leave their couches or release their restraints until the vehicle is upright. For nominal mission, post landing activities must not require the crew to stand without assistance by the SAR personnel.
- d. The crew shall not be required to perform any tasks during transient environments associated with parachute opening or disreefing, landing retrorocket firing, or landing impact.
- e. "Not accommodated" as used in Figure 4.10-1 specifies that the crew shall not be required to perform the activity. This does not necessarily imply that the crew is not able to perform the activity.
- f. Post Landing items 10 thru 14 are considered off-nominal/non-routine activities.

Potential Crew Activity/ Implementation	Design Requirements/Constraints	
	Environment	
	$2 < g_x < 2$	$2 < g_x < 4$
1. Monitor displays: - Alpha-numerics - Graphical - Analog - Discrete	a. Displays must be within eye movement limits of Fig. 9.2.4.2.2-2 with lateral head movement of $\pm 30^\circ$ and viewing distance limits of 9.2.4.2.2.a. b. Must not require lifting the head.	a. Displays must be within eye movement limits of Fig. 9.2.4.2.2-2 with lateral head movement of $\pm 30^\circ$ and viewing distance limits of 9.2.4.2.2.a. b. Must not require lifting the head.
2. Read checklist data: a. Computer screen b. Hard copy	a. See 1.a., 1.b. b. Hard copy must be within visibility limits of 2.a and reach envelope of 9.3.3.3.1.a.	a. See 1.a., 1.b. b. Hard copy must be within visibility limits of 2.a and reach envelope of 9.3.3.3.1.a.
3. Actuate discrete controls: - Toggle - Push button - Keyboard - Rotary	a. Controls must be within visibility limits of 1.a or meet the blind operation requirements specified in 9.3.3.1.g and within reach envelope of 9.3.3.3.1.a. b. Keystroke requirements should be minimized.	a. Controls must be within visibility limits of 1.a or meet the blind operation requirements specified in 9.3.3.1.g and within reach envelope of the supported forearm. b. Keystroke requirements should be minimized.
4. Actuate analog controls: a. Rotary b. Linear	a. See 3.a. b. Specific applications must be approved.	a. Specific applications must be approved. b. Specific applications must be approved.
5. Communicate with Mission Control & SAR: a. Vex b. PTT	a. No constraints. b. See 3.a.	a. No constraints. b. See 3.a.
6. Monitor physical cues: a. Vehicle motion b. Aural (alarms) c. Aural (equipment operation) d. Out the window (visual)	a. Not accommodated. b. Aural alarms must meet the requirements specified in 9.4.4. c. Specific applications must be approved. d. Specific applications must be approved.	a. Not accommodated. b. Aural alarms must meet the requirements specified in 9.4.4. c. Not accommodated. d. Not accommodated.
7. Monitor patient: a. Direct visual observation of patient b. Monitor medical support equipment	a. Attendant must be able to directly view the full side view of the patient from the waist up within the head and eye movement specified in 9.2.4.2.2.c. b. The medical support equipment must be visible within the field of view specified in 9.2.4.2.2.c.	a. Attendant must be able to directly view the full side view of the patient from the waist up within the head and eye movement specified in 9.2.4.2.2.c. b. Not accommodated.

Figure 4.10-1 Capabilities of A Deconditioned Crew
Re-entry Through Final Descent

MSIS 460A

Potential Crew Activity/Implementation	Design Requirements/Constraints	
	Environment	
	1g Upright	1g Inverted
1. Monitor displays: - Alpha-numeric - Graphical - Analog - Discrete	a. Displays must be within eye and head movement limits of 9.2.4.2.2.c. and viewing distance limits of 9.2.4.2.2.a. Rapid head movement should not be required.	a. Displays must be within eye and head movement limits of 9.2.4.2.2.c. and viewing distance limits of 9.2.4.2.2.a. Rapid head movement should not be required.
2. Read checklist data: a. Computer screen b. Hard copy	a. See 1.a. b. Hardcopy must be within visibility limits of 2.a. and reach envelope of 3.3.3.3.1.a.	a. See 1.a. b. Hardcopy must be within visibility limits of 2.a. and reach envelope of 3.3.3.3.1.a.
3. Actuate discrete controls: - Toggle - Push button - Keyboard - Rotary	a. Controls must be within visibility limits of 1.a. or meet the blind operation actuation requirements of 9.3.3.1.g. and within reach envelope of 3.3.3.3.1.a.	a. Controls must be within visibility limits of 1.b. or meet the blind operation actuation requirements of 9.3.3.1.g. and within reach envelope of 3.3.3.3.1.a.
4. Actuate analog controls: a. Rotary b. Linear	a. See 3.a. b. Specific applications must be approved.	a. See 3.a. b. Specific applications must be approved.
5. Communicate with Mission Control & SAR: a. Vox b. PTT	a. No constraint. b. No constraint.	a. Crew must be restrained in couch. b. Crew must be restrained in couch.
6. Monitor physical cues: a. Vehicle motion b. Aural (alarms) c. Aural (equipment operation) d. Out the window (visual)	a. Only inverted or upright attitude determination is accommodated. b. Aural alarms must meet the requirements specified in 9.4.4. Crew must be able to discern cues from couch. c. Specific applications must be approved. d. Specific applications must be approved.	a. Only inverted or upright attitude determination is accommodated. b. Aural alarms must meet the requirements specified in 9.4.4. Crew must be able to discern cues from couch. c. Specific applications must be approved. d. Specific applications must be approved. Crew must be able to discern cues from couch.
7. Monitor patient: a. Direct visual observation of patient. b. Monitor medical support equipment.	a. No constraint. b. No constraint.	a. Attendant must be able to directly view the full side view of the patient from the waist up within the head and eye movement specified in 9.2.4.2.2.c. b. Medical support equipment must be visible within the field of view specified in 9.2.4.2.2.c.

Figure 4.10-1 Capabilities of a Deconditioned Crew (continued)
Post-Landing

Potential Crew Activity/ Implementation	Design Requirements/Constraints	
	Environment	
	1g Upright	1g Inverted
8. Adjust medical equipment and provide medical assistance to patient.	a. No constraint. b. Attendant may exit couch to provide assistance. The crew member must not be required to stand.	Not accommodated.
9. Assist patient in eating, drinking and personal hygiene.	a. No constraint. b. Attendant may exit couch to provide manual assistance. The crew member must not be required to stand.	Not accommodated.
10. Operate auxiliary equipment, retrieve supplies, and perform personal hygiene functions.	a. Crew may exit couch to perform activities. b. Unrestrained mass should be less than 12 lbs. c. Control activation must meet the requirements specified in 9.3.3. d. Crew strength capabilities should be as specified in 4.9.3. e. Contingency operations which require the crew member to stand must be approved.	Not accommodated.
11. Reconfigure couches or panels after landing. Operate lock/ release mechanism, Raise or lower seat pan or equipment.	a. Crew may exit couch to perform activity. b. Unrestrained mass should be less than: - Dynamic (water) envr. - 12 lbs. - Static (land) envr. - 20 lbs. c. Restrained loads should not exceed capabilities specified in 4.9.3. d. Contingency operations which require the crew member to stand must be approved.	Not accommodated.

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Figure 4.10-1 Capabilities of a Deconditioned Crew (continued)
Post-Landing

Potential Crew Activity/ Implementation	Design Requirements/Constraints	
	Environment	
	1g Upright	1g Inverted
12. Open hatch / Operate latch mechanism	<ul style="list-style-type: none"> a. Crew may exit couch to perform activity b. No unrestrained mass. c. Restrained loads should not exceed crew strength capabilities specified in 4.9.3. d. Contingency operations which require the crew member to stand must be approved. 	Not accommodated.
13. Egress without outside assistance	<ul style="list-style-type: none"> a. Crew may exit couch to perform activity. b. Crew is assumed to have the physical capability and strength of a normally conditioned crew as stated in 4.9.3. 	Not accommodated.
14. Deploy survival equipment	<ul style="list-style-type: none"> a. Single crew member should not be required to lift more than 20 lbs. overhead. b. Mass of single package of survival equipment should not exceed 50 lbs. 	Not accommodated.

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Figure 4.10-1 Capabilities of a Deconditioned Crew (continued)
Post-Landing

5.0 NATURAL AND INDUCED ENVIRONMENTS

5.1 ATMOSPHERE

5.1.1 Introduction - N/A

5.1.2 Atmosphere Design Considerations - N/A

5.1.3 Atmosphere Design Requirements

Paragraph 5.1.2.4.1 through 5.1.2.4.3 present requirements which are directly applicable to the design of respirable atmospheres for the Assured Crew Return Vehicle cabin atmosphere.

5.1.3.1 Atmosphere Composition and Pressure Design Requirements

The following design requirements shall apply to the composition and pressure of the Assured Crew Return Vehicle cabin atmosphere:

a. Internal Environment - An internal environment to support and maintain crew health throughout detached operational phases of the ACRV shall be provided in accordance with the requirements given in Figure 5.1.3.1-1.

b. Atmospheric Revitalization - The ACRV atmosphere shall be revitalized every 5 to 7 minutes to provide a safe and habitable environment for the crew. This system will be referred to as the Environmental Control Life Support System (ECLSS).

c. Atmosphere Control and Supply :

1. Means to control and maintain atmospheric pressure and composition to the levels defined in Figure 5.1.3.1-1 shall be provided.

2. The controls shall be provided in the ACRV and shall be operable by a crewmember in a shirt sleeve environment.

3. Normally, the controls shall operate autonomously with limited or no crew intervention necessary.

d. ECLSS Design Requirements - The systems of the ECLSS will provide atmospheric pressure and composition control, temperature and humidity control and atmospheric revitalization for the ACRV.

5.1.3.2 Atmosphere Monitoring Design Requirements

The ACRV design shall consider Space Station interfaces to maximize effective utilization of Space Station atmospheric monitoring capabilities while the ACRV is attached to the station.

PARAMETER	UNITS	OPERATIONAL (detached)	ENTRY & LANDING	POST LANDING
CO ₂ Partial Pressure	mmHg	0-7.6	0-7.6	0.0-15.0
Temperature	deg. F	65-80	60-90	see note 1
Dew Point	deg. F	35-70	35-70	see note 1
Ventilation	Ft/min	15-40	15-40	see note 1
O ₂ Partial Pressure	psia	2.83-3.35	2.83-3.35	2.3-3.45*
Diluent Gas (N ₂)	psia	balance	balance	balance
Total Pressure	psia	14.5-14.9	14.5-14.9	14.5-14.9*
Filter Particle Size	microns	300	300	300

ACRV Respirable Atmosphere Requirements (Customary Units)

PARAMETER	UNITS	OPERATIONAL (detached)	ENTRY & LANDING	POST LANDING
CO ₂ Partial Pressure	N/m ²	0-1.01	0-1.01	0-1.99
Temperature	deg. C	18.3-26.7	15.6-32.2	see note 1
Dew Point	deg. C	1.7-21.1	1.7-21.1	see note 1
Ventilation	M/sec	.076-.203	.076-.203	see note 1
O ₂ Partial Pressure	Kp2	19.5-23.1	19.5-23.1	15.8-23.8*
Diluent Gas (N ₂)	Kp2	balance	balance	balance
Total Pressure	Kp2	100-102.7	100-102.7	100-102.7*
Filter Particle Size	microns	300	300	300

ACRV Respirable Atmosphere Requirements (SI Units)

Reference: 37, Figure 20201-A, B
 92, pages 2, 42, 55
 111, page 683
 195, page 27
 254, Table 11.2, Para. 11.1.1/4
 288, page 5

278
 321, Table 2-4-1
 323, Table C-4-IX, page C-4-45
 324, Table 2-9

Note 1 - Heat storage is limited to 300 BTUs/crewmember
 * Includes Ambient Partial Pressures

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Figure 5.1.3.1-1 Requirements for Space Module Respirable Requirements

5.2 MICROGRAVITY

5.2.1 Introduction - N/A

5.2.2 Microgravity and Its Counterparts Design Considerations - N/A

5.2.3 Microgravity Design Requirements - N/A

5.3 ACCELERATION

5.3.1 Introduction - N/A

5.3.2 Acceleration Design Considerations - N/A

5.3.3 Acceleration Design Requirements

Figure 5.3.3-1 shows the coordinate system nomenclature that is used in this document. (Note: Left-Handed System). This system is based on the direction a body organ (e.g., the heart) would be displaced by acceleration. The table in Figure 5.3.3-1, which is based on displacement of body fluids, explains the most commonly employed terms.

5.3.3.1 Linear Acceleration Design Requirements

5.3.3.1.1 Entry Acceleration Design Requirements

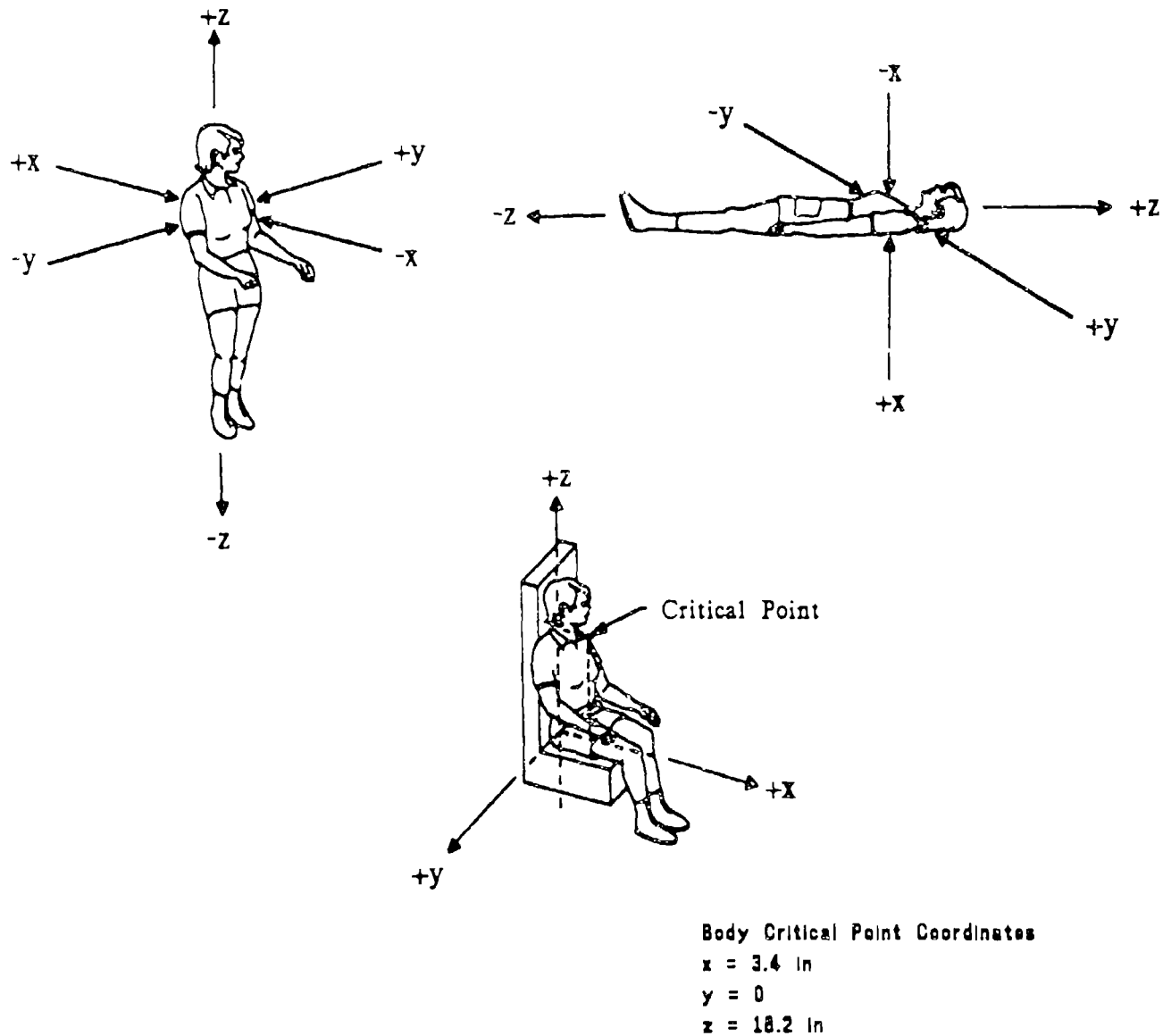
The ACRV shall be capable of limiting sustained entry acceleration to be no greater than 4 G's in the +/- Gx direction, 1 G in the +/- Gy direction, and 0.5 G's in the +/- Gz direction.

5.3.3.2 Entry Spin Limitation Design Requirements

The ACRV shall not spin at a rate greater than 5 rpm.

5.3.3.3 Impact Acceleration Design Requirements

At landing, crewmembers shall not be exposed to impact accelerations at the body critical point greater than those allowed by the Whole-Body Dynamic Response Risk Model for a 0.5% risk of injury with risk criterion limited to value not to exceed 1.0. The body critical point is the location in the seat coordinate system at which the dynamic response of the body is computed and corresponds roughly to the midthoracic center of mass. The method to compute acceptable critical point resultant acceleration exposures is described in the following paragraphs.



Reference: 101, page 9
With Updates

Note:

The origin of the seat coordinate system is at the Seat Reference Point (S.R.P.) as defined in Figure 3.3.3.3-1 where the Y-Z plane is the compressed seat-back-tangent plane

Figure 5.3.3-1 Seat Coordinate System and the Location of the Body Critical Point

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LINEAR MOTION	DIRECTION OF ACCELERATION		
	Acting Force	Acceleration Description	Verticular Description
Forward	+ax	Forward Acceleration	Eye Balls In
Backward	-ax	Backward Acceleration	Eye Balls Out
Upward	+az	Headward Acceleration	Eye Balls Down
Downward	-az	Footward Acceleration	Eye Balls Up
To Right	+ay	R. Lateral Acceleration	Eye Balls Left
To Left	-ay	L. Lateral Acceleration	Eye Balls Right

Reference: 380 With Updates

Note: Large letter, G, used as unit to express inertial resultant to whole body acceleration in multiples of the magnitude of the acceleration of gravity, $g_0 = 980.665 \text{ cm/sec}^2$ or 32.1739 ft/sec^2 .

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Figure 5.3.3-1 Acceleration Environment Coordinate System Used in MSIS (cont.)

a. **Seat Coordinate System** - The seat coordinate system and the dimensions that define the location of the critical point of the body are given in Figure 5.3.3-1.

b. **Acceleration Evaluation Method** - If the linear resultant acceleration at any point in the seat coordinate system and the angular velocity and acceleration are known, then the motion of the seat is defined and the linear resultant acceleration at the critical point can be computed. The acceptability of the acceleration at the critical point is evaluated by first computing the dynamic response (DR) as a function of time for each major axis (X, Y, and Z). The dynamic response of the body is modeled by a mass, spring and damper system attached to the seat.

The dynamic response is computed for each axis using the following equation in Figure 5.3.3-1.

$$\ddot{\delta} + 2\tau\omega_n\dot{\delta} + (\omega_n)^2\delta = \ddot{\zeta}$$

$$DR(\tau) = \frac{(\omega_n)^2\delta(\tau)}{g}$$

where:

- $\ddot{\delta}$ is the acceleration of the dynamic response model mass relative to the critical point acceleration (ft./sec²).
- $\dot{\delta}$ is the relative velocity between the critical point and the model mass (ft./sec.)
- δ is the compression of the model spring (ft.)
- τ is the damping coefficient ratio (0.2 for the x axis, 0.08 for the y axis, and 0.224 for the z axis).
- ω_n is the undamped natural frequency of the model (82.8 rad/sec for the x axis, 58.0 rad/sec for the y axis, and 52.9 rad/sec for the z axis).
- $\ddot{\zeta}$ is the acceleration component along the pertinent axis acting at the critical point (ft./sec²).
- g is the acceleration due to gravity (32.2 ft./sec²).
- (τ) indicates that the parameter is determined as a function of time.

Figure 5.3.3-1 Dynamic Response For Each Axis

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After the dynamic response for each axis has been computed, the whole-body dynamic response risk is computed using the following equation in Figure 5.3.3.3-2.

$$\beta = \sqrt{\left(\frac{DRX_{(t)}}{DRX_L} \right)^2 + \left(\frac{DRY_{(t)}}{DRY_L} \right)^2 + \left(\frac{DRZ_{(t)}}{DRZ_L} \right)^2}$$

where:

The subscript L denotes the limiting dynamic response values assigned for each major axis for healthy deconditioned, and ill or injured deconditioned crew members. These values are tabulated in Figure 5.3.3.3-3.

DRX is the dynamic response computed from the X axis acceleration component at the critical point.

DRY is the dynamic response computed from the Y axis acceleration component at the critical point.

DRZ is the dynamic response computed from the Z axis acceleration component at the critical point.

β is the whole-body dynamic response risk criterion

(t) indicates the parameter is a function of time

The value of β computed must be less than or equal to one for the whole-body impact acceleration to be acceptable.

Figure 5.3.3.3-2 Whole-body Dynamic Response Risk

Crew Member Condition*	DRX _L		DRY _L		DRZ _L	
	DRX > 0	DRX < 0	DRY > 0	DRY < 0	DRZ > 0	DRZ < 0
Healthy Deconditioned	35	-28	14	-14	15.2	-9
Ill or Injured Deconditioned	26.3	-21	10.5	-10.5	11.4	-6.8

- * The limit values apply to crewmembers restrained to a seat by conventional restraints such as a lap belt, two shoulder straps and a crotch strap.

Figure 5.3.3.3-3 Dynamic Response Limit Values

5.4 ACOUSTICS

5.4.1 Introduction - N/A

5.4.2 Acoustics Design Considerations - N/A

5.4.3 Acoustics Design Requirements

This section defines the basic environmental limitations and criteria that the designer shall apply to the design of crew stations and other habitable compartment areas. Noise levels shall be specified in terms of A-weighted sound level, L(A). Noise exposure over 24 hour periods shall be specified in terms of the equivalent A-weighted sound level L(A) eq. The maximum allowable on orbit continuous broad band sound pressure exposure limits produced by the summation of all individual sound pressures from all sources, including all operating systems, subsystems and payloads, considered over a 24 hour period are defined in the following paragraphs.

5.4.3.1 General Acoustic Design Requirements

The following general acoustic design requirements shall be observed:

- a. General Acoustic Design - Noise generation and penetration shall be controlled to the extent that acoustic energy will not cause personnel injury, interfere with voice or any other communications or contribute to the degradation of overall man-machine effectiveness.

(All sound pressure levels in decibels are referenced to 20 u-Pascals unless otherwise stated and are to be measured at or translated to the outer ears of crewmembers.)

- b. Equipment Noise - All noisy equipment shall be mounted and located to reduce noise at crewmember locations.

5.4.3.2 Noise Exposure Requirements

The following types of noise shall be taken into account:

- a. Wide-band random noise (22.4 to 11,200 Hz).
- b. Narrow-band noise and tones.
- c. Impulse noise.
- d. Infrasonic and ultrasonic noise.

There are three sets of noise requirements that shall be satisfied depending on crewmember task and acceleration regimes: 1) hearing conservation, 2) voice communication, and 3) annoyance.

5.4.3.2.1 Hearing Conservation Noise Exposure Requirements

- a. Maximum Noise Exposure - A maximum noise exposure of 115 dB(A) is allowable, providing the duration does not exceed two minutes.
- b. Hearing Protection Devices - Hearing protection devices shall be provided for use during exposure to noise levels of 85 dB(A) or greater.

5.4.3.2.1.1 Wide-Band, Long-Term Hearing Conservation Noise Exposure Requirements

The following long-term, wide-band hearing conservation noise exposure criteria shall apply:

- a. Hazard Level - Noise of constant sound levels of 85 dB(A) and greater are considered hazardous regardless of the duration of exposure. Total exposure shall not exceed an average of 80dB(A).
- b. Allowable Noise Exposure - A noise exposure of 80 to 84 dB for up to eight hours duration without hearing protection is allowable but not desirable.
- c. Unacceptable Noise Levels - Crewmembers shall not be exposed to continuous noise levels that exceed 120 dB in any octave band or 135 dB OASPL under any circumstances.

5.4.3.2.1.2 Narrow-Band, Long-Term Hearing Conservation Noise Exposure Requirements

The relative sound pressure levels of narrow-band components, pure-tones, and beat frequencies shall be limited to a level at least 10 dB lower than the allowed maximum sound pressure level of the octave-band that contains the component.

5.4.3.2.1.3 Impulse Hearing Conservation Noise Exposure Requirements

Maximum Noise Level (Hearing Conservation Criteria) - Impulse sound is a change in sound pressure level of more than 10 dB in one second or less. Impulse noise shall not exceed 140 dB peak pressure level to meet hearing conservation criteria for unprotected ears.

5.4.3.2.1.4 Infrasonic, Long-Term Annoyance Noise Exposure Requirements

The following infrasonic noise annoyance criteria shall apply:

- a. Infrasonic Sound Pressure Level - Infrasonic sound pressure level shall be less than 120 dB in the frequency range of 1 to 16 Hz.
- b. Hearing Protection - Passive hearing protection devices are permissible for low-frequency infrasonic noise control.

5.4.3.2.1.5 Ultrasonic, Long-Term Annoyance Noise Exposure Requirements

The following ultrasonic noise annoyance criteria shall apply:

- a. Hearing Conservation Measures - Hearing conservation measures shall be initiated when the ultrasonic criteria provided in Figure 5.4.3.2.1.5-1 are exceeded.
- b. Hearing Protection - Ultrasonic noise hearing protection shall be provided where overexposure is possible in contingency cases in a way that communication is not hampered.

5.4.3.2.2 Voice Communication Noise Exposure Requirements

5.4.3.2.2.1 Direct Voice Communications Noise Exposure Requirements

Background Noise Level - Background noise for work areas shall not exceed the NC 50 contour unless otherwise specified.

One-third octave band center frequency, kHz	One-third octave band level in dB
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115

VB 401

Reference: 281, Page 1-3

Figure 5.4.3.2.1.5-1 Airborne High Frequency and Ultrasonic Hazard Noise Limits

5.4.4 Example Acoustics Design Solutions

The control of noise involves three interdependent elements:

- Control at the source.
- Interruption or absorption along the transmission path.
- Personal hearing protection.

Noise reduction techniques that can be applied to the ACRV are the same as used in industrial and building noise control. Figure 5.4.4-1 lists typical methods to control noise at the source.

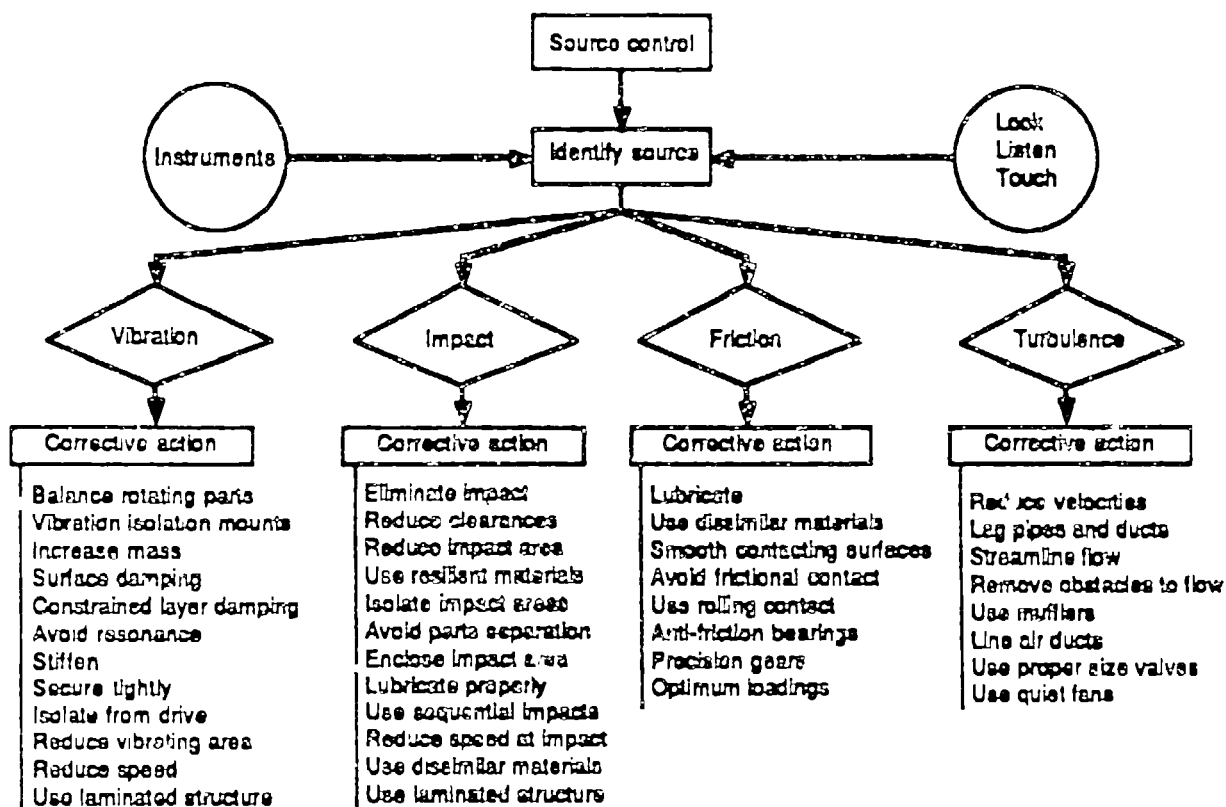


Figure 5.4.4-1 Typical Noise Source Corrective Actions

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5.5 VIBRATION

5.5.1 Introduction - N/A

5.5.2 Vibration Design Considerations - N/A

5.5.3 Vibration Design Requirements

General Vibration Design - Vibration generation and penetration shall be controlled to the extent that vibration energy will not cause personnel injury, contribute to the degradation of overall man/machine effectiveness during manned periods.

5.5.3.1 General Vibration Design Requirements

Equipment Vibration - System design shall include vibration control provisions.

5.5.3.2 Vibration Exposure (0.1 to 1 Hz) Design Requirements

5.5.3.2.1 Severe Discomfort Boundary - N/A

5.5.3.2.2 Decreased Proficiency Boundary

The following acceleration limits for 0.1 to 0.63 Hz for crewmember stations and work areas shall apply:

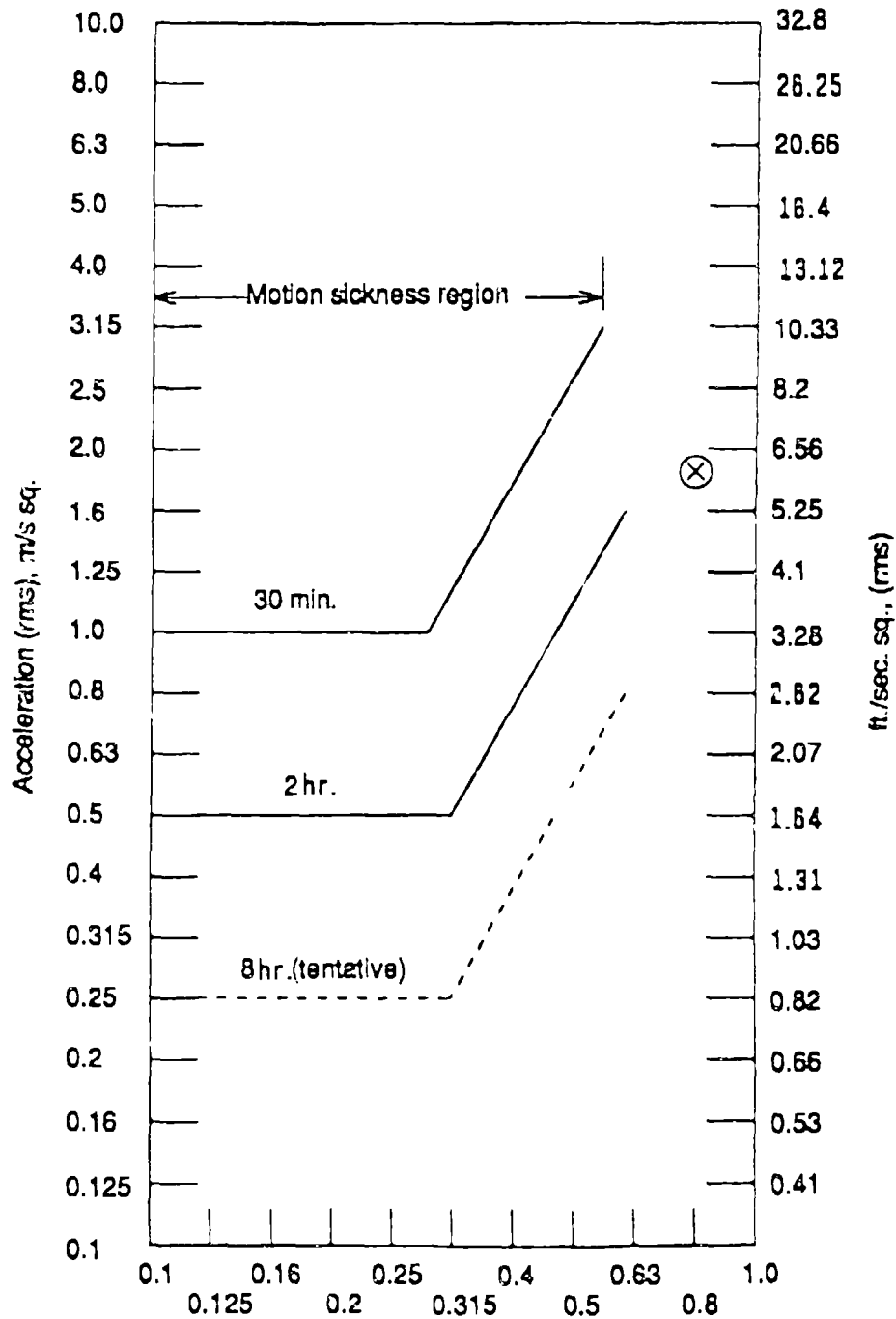
- a. Longitudinal Vibration - For tasks requiring writing and fine manual control, vibration rms-values shall not exceed 1.75 m/sec^2 .
- b. Transverse Vibration - For transverse vibration use 25% of values shown in Figure 5.5.3.2.2-1.
- c. Visual Acuity Effects - For whole body vibration in the ranges of 3 to 11 Hz or 22 to 30 Hz, provisions shall be made to protect the crew from loss of visual acuity.

5.5.3.3 Vibration Exposure (1 to 80 Hz) Design Requirements

5.5.3.3.1 Fatigue-Decreased Proficiency Boundary

The following vibration acceleration limits for 1 to 80 Hz for crewmember stations and work areas during orbital and planetary conditions shall apply:

- a. Longitudinal Vibration - Vibration acceleration exposure shall not exceed the limits shown in Figure 5.5.3.3.1-1 for z-axis direction, unless specified otherwise.
- b. Transverse Vibration - Vibration acceleration exposure shall not exceed the limits shown in Figure 5.5.3.3.1-2 for x, y-axis directions, unless specified otherwise.



Frequency or center frequency of third-octave band, Hz

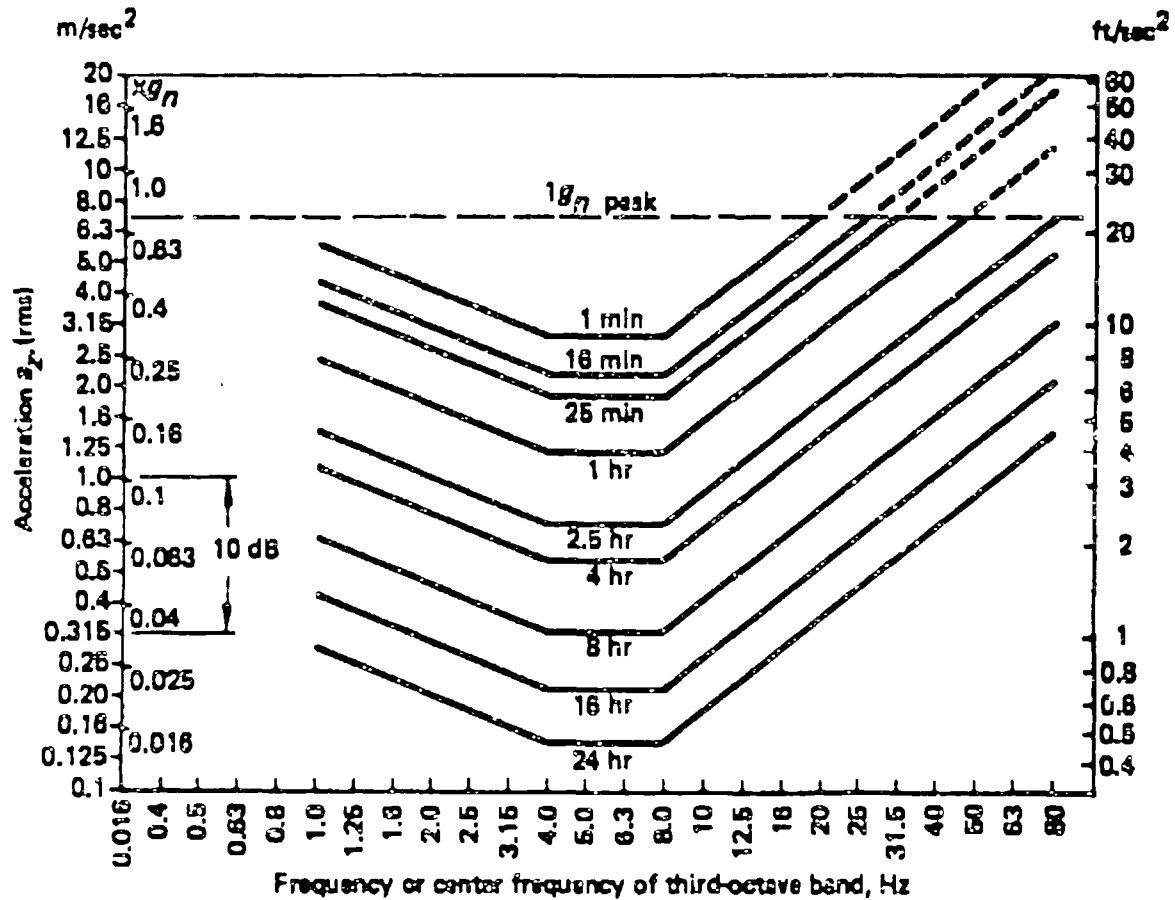
⊗ Snyder, Fred (Boeing, 1964) Reference a 2 hour exposure

Note: Eight-hour curve created by extrapolation based on 30 min. and 2 hour testing

Reference: 101, page 44, add. 2-1982 E with updates

Figure 5.5.3.2.2-1 Longitudinal (Z-Axis) Acceleration Limits
(0.1 to 0.63 Hz) "Severe Discomfort Boundaries"

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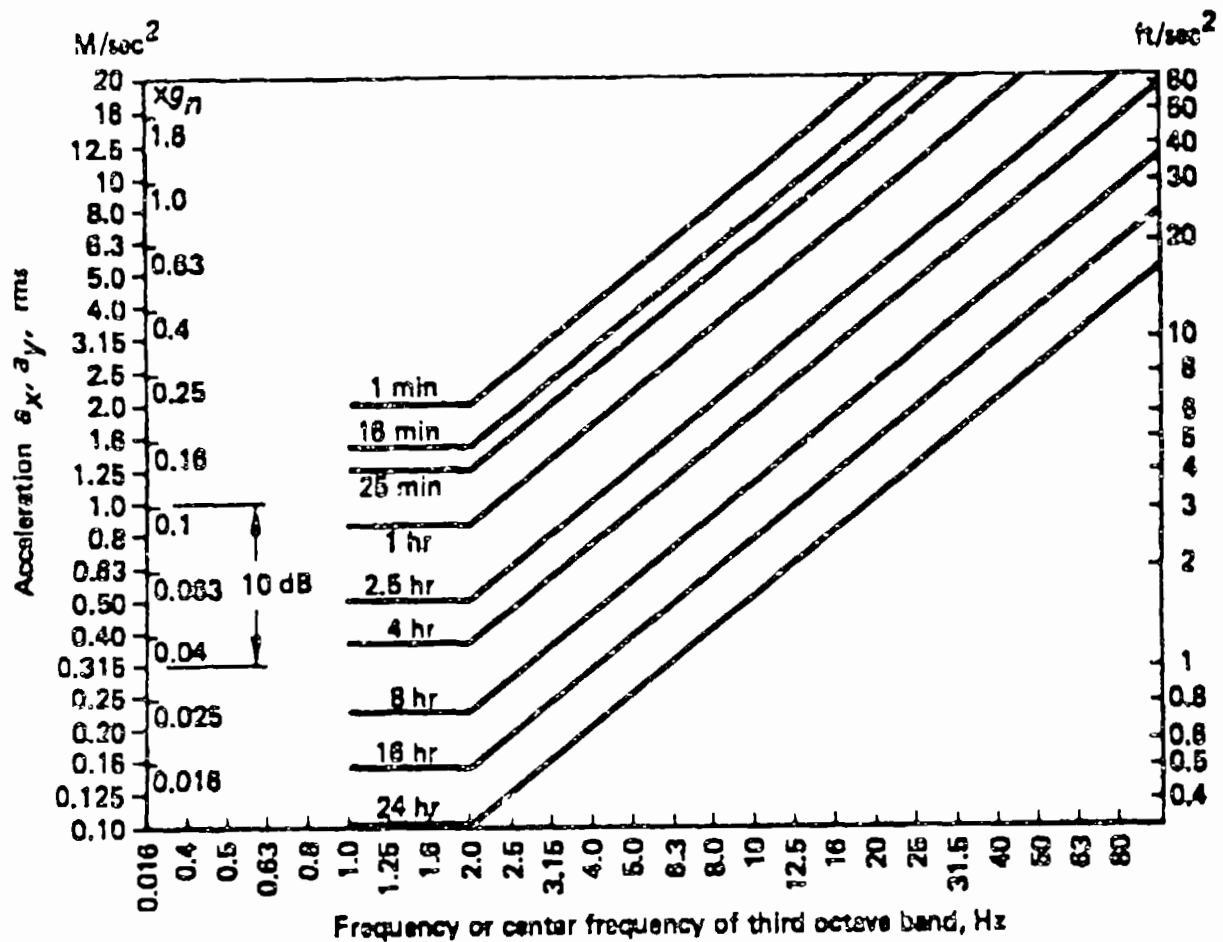
To obtain:

- "exposure limits": multiply acceleration values by 2 (6 dB higher);
- "reduced comfort boundary": divide acceleration values by 3.15 (10 dB lower)

Reference: 2, Figure 42, page 175
101, page 10

V3 146

**Figure 5.5.3.3.1-1 Longitudinal (z-axis) Acceleration Limits
"Fatigue-decreased Proficiency Boundary"**



To obtain:

- "exposure limits": multiply acceleration values by 2 (6 dB higher);
- "reduced comfort boundary": divide acceleration values by 3.15 (10 dB lower)

Reference: 2, Figure 42, page 175
101, page 12

**Figure 5.5.3.3.1-2 Transverse (x-axis, y-axis) Acceleration Limits
"Fatigue-decreased Proficiency Boundary"**

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c. Visual Acuity Effects - For whole body vibration in the ranges of 3 to 11 Hz or 22 to 30 Hz, provisions shall be made to protect the crew from loss of visual acuity.

5.5.3.3.2 Vibration Exposure Limit - N/A

5.5.3.3.3 Reduced Comfort Boundary - N/A

5.6 (THIS PARAGRAPH WAS NOT USED)

5.7 RADIATION

5.7.1 Introduction - N/A

5.7.2 Ionizing Radiation

5.7.2.1 Ionizing Radiation Design Considerations - N/A

5.7.2.2 Ionizing Radiation Design Requirements

5.7.2.2.1 Ionizing Radiation Exposure Limits - N/A

5.7.2.2.2 Ionizing Radiation Protection Design Requirements

The following strategies shall be used to implement radiation protection features for crewmembers on the Assured Crew Return Vehicle at 28.5 deg:

a. Radiation Protection - The design of the ACRV shall include the necessary radiation protection features (shielding, radiation monitoring and dosimetry, etc.) for all expected missions to ensure that the crew dose rates are kept as low as reasonably achievable (ALARA levels) and that the maximum allowable dose limits are not exceeded.

b. Use of Onboard mass - The design and layout of the ACRV shall consider the use of onboard mass as radiation shielding.

5.7.3 Non-Ionizing Radiation

5.7.3.1 Non-Ionizing Radiation Design Considerations - N/A

5.7.3.2 Non-Ionizing Radiation Design Requirements

5.7.3.2.1 Non-Ionizing Radiation Exposure Limits

The following non-ionizing radiation exposure limits shall apply:

a. Radiofrequency Electromagnetic Fields Exposure Limits - The American National Standards Institute (ANSI) Radio Frequency Protection Guides (RFPG) for occupational exposure are shown in Figure 5.7.3.2.1-1 and illustrated in Figure 5.7.3.2.1-2.

b. Optical Laser Radiation Exposure Limits - The following laser exposure limits [contained in both the ANSI and American Conference of Governmental Industrial Hygienists (ACGIH) standards] apply to continuous lasers [for repetitively pulsed lasers, the additional stipulations given in the ANSI and ACGIH standards shall apply (Z136.1-1980, ANSI Standard for the Safe Use of Lasers, May 23, 1986; and ACGIH Threshold Limit Values and Biological Exposure Indices for 1987-1988; respectively.)].

1. Determination of "Point Source" or "Extended Source" Laser Exposure Criteria Applicability - Exposure limits for "Extended Sources" shall apply to sources that subtend a visual angle measured at the eye greater than the alpha-minimums given in Figure 5.7.3.2.1-3. "Point Source" exposure limits shall apply to sources with alpha-minimums less than those shown.

2. Point Source Laser Eye Exposure Limits - The eye exposure limits given in Figure 5.7.3.2.1-4 shall apply to all point source lasers.

3. Extended Source Laser Eye Exposure Limits - The eye exposure limits given in Figure 5.7.3.2.1-5 shall apply to all extended source lasers.

4. Extended Source Laser Skin Exposure Limits - The skin exposure limits shown in Figure 5.7.3.2.1-6 shall apply to all extended source lasers.

5. Exposure Limits for Commonly Available Types of Lasers - The eye and skin laser exposure limits for specific types of lasers shown in Figure 5.7.3.2.1-7 shall apply (these limits are derived from the limits given in the above figures).

c. Incoherent Ultraviolet Optical Radiation Exposure Limits

1. Determination of Combined Continuous and Pulsed UV Exposure Average - The irradiance from continuous exposure and radiant exposure for time-limited or pulsed exposures to the eye or skin shall be averaged over the area of a circular measurement aperture of less than 1mm (0.03937 in.) diameter.

2. UV-A Spectrum (315-400 nm) Radiation Exposure Limits - The total irradiance incident upon unprotected skin shall be less than 10 W/m^2 ($0.053 \text{ BTU/ft}^2 \cdot \text{min}$) for periods of exposure longer than 1000 seconds. For exposure times less than 1000 seconds, radiant exposure shall be less than 1 J/cm^2 (0.006 BTU/in^2).

Table 1
Radio Frequency Protection Guides

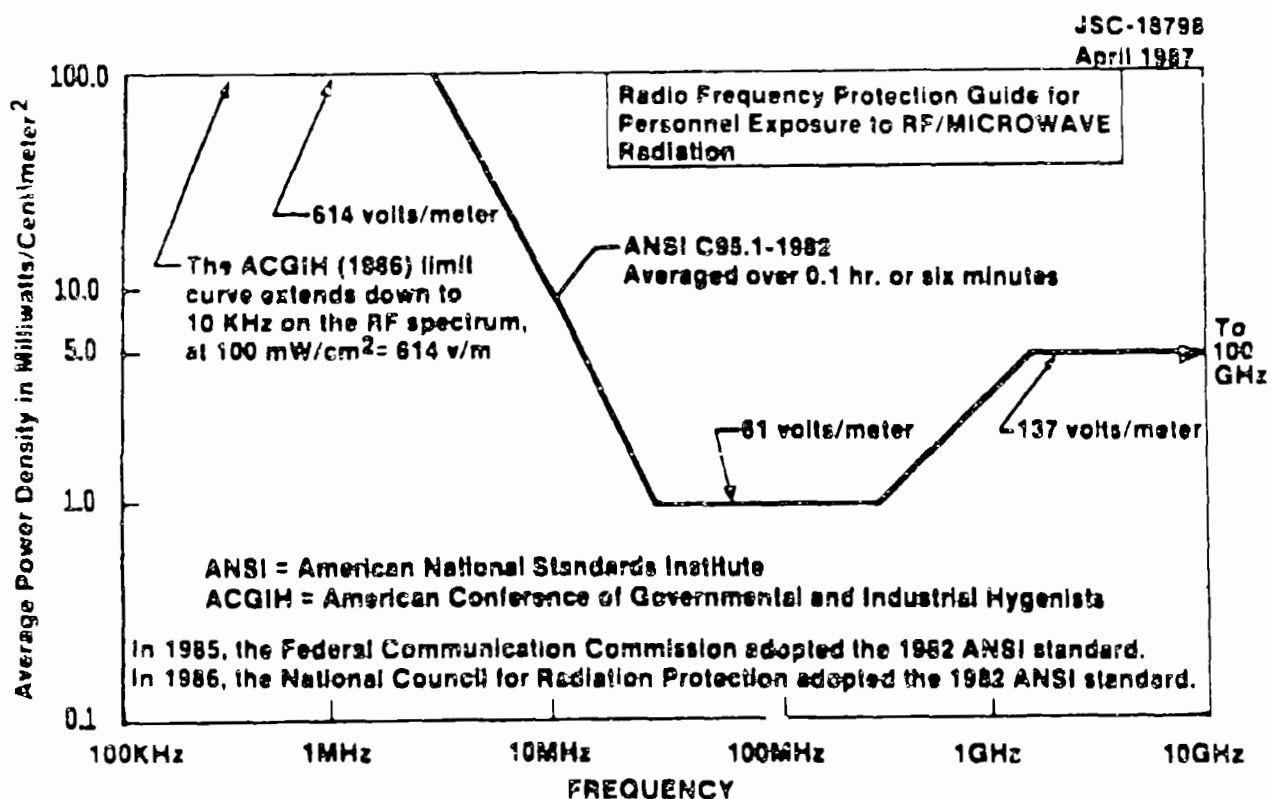
1	2	3	4
Frequency Range (MHz)	E^2 (V^2/m^2)	H^2 (A^2/m^2)	Power Density (mW/cm^2)
0.3 — 3	400 000	2.5	100
3 — 30	4000 ($900/f^2$)	0.025 ($900/f^2$)	$900/f^2$
30 — 300	4000	0.025	1.0
300 — 1500	4000 ($f/300$)	0.025 ($f/300$)	$f/300$
1500 — 100 000	20 000	0.125	5.0

Note: f = frequency (MHz).

Reference: 382, Table 1 With Updates

Figure 5.7.3.21-1 Occupational Exposure Limits for Radiofrequency Electromagnetic Fields

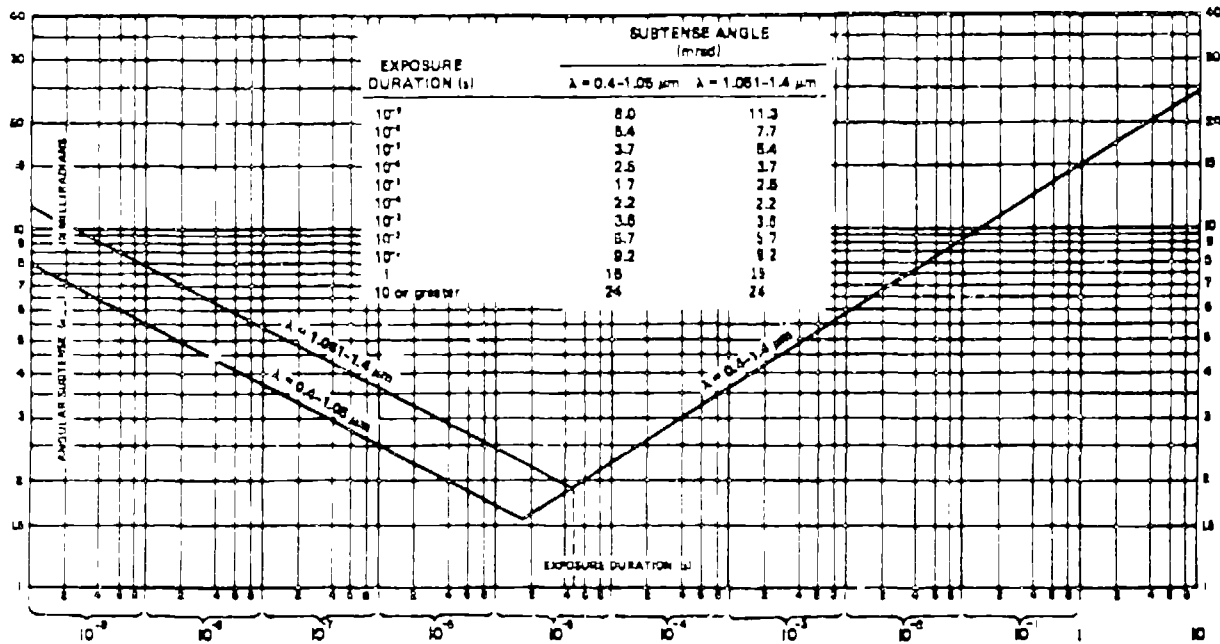
V6 420



Reference: 384

Figure 5.7.3.21-2 Occupational Exposure Limits Illustrated to show whole-body resonance effects around 100 MHz

V6 410



Note: Extended sources have an angular subtense or apparent visual angle $\geq 1^\circ$. Angular subtenses (apparent visual angles) $< 1^\circ$ are considered intrabeam viewing.

Reference: 383, Figure 3

Figure 5.7.3.2.1-3 Alpha-minimums used to determine "Point Source" or "Extended Source" Laser Exposures

Wavelength, λ (μm)	Exposure Duration, t (s)	Maximum Permissible Exposure (MPE)	Notes for Calculation and Measurement
Ultraviolet			
0.200-0.302	$10^{-2}-3 \times 10^6$	$3 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	or $0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$, whichever is lower 1-mm limiting aperture
0.303	$10^{-2}-3 \times 10^6$	$4 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.304	$10^{-2}-3 \times 10^6$	$6 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.305	$10^{-2}-3 \times 10^6$	$1.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.306	$10^{-2}-3 \times 10^6$	$1.6 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.307	$10^{-2}-3 \times 10^6$	$2.5 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.308	$10^{-2}-3 \times 10^6$	$4.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.309	$10^{-2}-3 \times 10^6$	$6.3 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.310	$10^{-2}-3 \times 10^6$	$1.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.311	$10^{-2}-3 \times 10^6$	$1.6 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.312	$10^{-2}-3 \times 10^6$	$2.5 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.313	$10^{-2}-3 \times 10^6$	$4.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.314	$10^{-2}-3 \times 10^6$	$6.3 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^{-9}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	10^{-10^3}	$1 \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^3-3 \times 10^4$	$1 \times 10^{-3} \text{ W} \cdot \text{cm}^{-2}$	
Visible and Near Infrared*			
0.400-0.700	$10^{-9}-1.8 \times 10^{-5}$	$5 \times 10^{-7} \text{ J} \cdot \text{cm}^{-2}$	7-mm limiting aperture
0.400-0.700	$1.8 \times 10^{-5}-10$	$1.8 t^{3/4} \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.400-0.550	10^{-10^4}	$10 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.550-0.700	$10^{-7} t_1$	$1.8 t^{3/4} \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.550-0.700	7_1-10^4	$10 C_B \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.400-0.700	$10^4-3 \times 10^4$	$C_B \times 10^{-6} \text{ W} \cdot \text{cm}^{-2}$	
0.700-1.050	$10^{-9}-1.8 \times 10^{-5}$	$5 C_A \times 10^{-7} \text{ J} \cdot \text{cm}^{-2}$	
0.700-1.050	$1.8 \times 10^{-5}-10^3$	$1.8 C_A t^{3/4} \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
1.051-1.400	$10^{-9}-5 \times 10^{-5}$	$5 \times 10^{-6} \text{ J} \cdot \text{cm}^{-2}$	
1.051-1.400	$5 \times 10^{-5}-10^3$	$9 t^{3/4} \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.700-1.400	$10^3-3 \times 10^4$	$320 C_A \times 10^{-6} \text{ W} \cdot \text{cm}^{-2}$	
Far Infrared			
1.4-10 ³	$10^{-9}-10^{-7}$	$10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
	$10^{-7}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
	>10	$0.1 \text{ W} \cdot \text{cm}^{-2}$	

NOTES: $C_A = 1$ for $\lambda = 0.400-0.700 \mu\text{m}$,
 $C_A = 10^{1.5(\lambda - 0.700)}$ for $\lambda = 0.700-1.050 \mu\text{m}$,
 $C_A = 5$ for $\lambda = 1.050-1.400 \mu\text{m}$,
 $C_B = 1$ for $\lambda = 0.400-0.550 \mu\text{m}$,
 $C_B = 10^{1.5(\lambda - 0.550)}$ for $\lambda = 0.550-0.700 \mu\text{m}$,
 $T_1 = 10 \times 10^{20(\lambda - 0.550)}$ for $\lambda = 0.550-0.700 \mu\text{m}$

Reference: 383, Table 5 With Updates

Figure 5.7.3.2.1-4 "Point Source" Laser Eye Exposure Limits

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Wavelength, λ (μm)	Exposure Duration, t (s)	Maximum Permissible Exposure (MPE)	Notes for Calculation and Measurement
Ultraviolet			
0.200-0.302	$10^{-2}-3 \times 10^4$	$3 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	or $0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$, whichever is lower
0.303	$10^{-2}-3 \times 10^4$	$4 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.304	$10^{-2}-3 \times 10^4$	$6 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.305	$10^{-2}-3 \times 10^4$	$1.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.306	$10^{-2}-3 \times 10^4$	$1.6 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.307	$10^{-2}-3 \times 10^4$	$2.5 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.308	$10^{-2}-3 \times 10^4$	$4.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.309	$10^{-2}-3 \times 10^4$	$6.3 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.310	$10^{-2}-3 \times 10^4$	$1.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.311	$10^{-2}-3 \times 10^4$	$1.6 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.312	$10^{-2}-3 \times 10^4$	$2.5 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	1-mm limiting aperture
0.313	$10^{-2}-3 \times 10^4$	$4.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.314	$10^{-2}-3 \times 10^4$	$6.3 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^{-9}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10-10^3$	$1 \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^3-3 \times 10^4$	$1 \times 10^{-3} \text{ W} \cdot \text{cm}^{-2}$	
Visible*			
0.400-0.700	$10^{-9}-10$	$10 t^{1/3} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	1-mm limiting aperture or a min, whichever is greater
0.400-0.550	$10-10^4$	$21 \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
0.550-0.700	$10-T_1$	$3.83 t^{3/4} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
0.550-0.700	T_1-10^4	$21 C_B \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
0.400-0.700	$10^4-3 \times 10^4$	$2.1 C_B 10^{-3} \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
Near Infrared*			
0.700-1.400	$10^{-9}-10$	$10 C_A t^{1/3} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	}
0.700-1.400	$10-10^3$	$3.83 C_A t^{3/4} \text{ J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
0.700-1.400	$10^3-3 \times 10^4$	$0.64 C_A \text{ W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$	
Far Infrared			
1.4-10 ³	$10^{-9}-10^{-7}$	$10^{-2} \text{ J} \cdot \text{cm}^{-2}$	}
	$10^{-7}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
	>10	$0.1 \text{ W} \cdot \text{cm}^{-2}$	

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NOTES: $C_A = 1$ for $\lambda = 0.400-0.700 \mu\text{m}$,
 $C_A = 10^{2.0(\lambda - 0.700)}$ for $\lambda = 0.700-1.050 \mu\text{m}$
 $C_A = 5$ for $\lambda = 1.051-1.400 \mu\text{m}$,
 $C_B = 1$ for $\lambda = 0.400-0.550 \mu\text{m}$,
 $C_B = 10^{1.5(\lambda - 0.550)}$ for $\lambda = 0.550-0.700 \mu\text{m}$
 $T_1 = 10 \times 10^{20(\lambda - 0.550)}$ for $\lambda = 0.550-0.700 \mu\text{m}$

Reference: 383, Table B With Updates

Figure 5.7.3.21-5 "Extended Source" Laser Eye Exposure Limits

W8 425

Wavelength, λ (μm)	Exposure Duration, t (s)	Maximum Permissible Exposure (MPE)	Notes for Calculation and Measurement
Ultraviolet			
0.200-0.302	$10^{-2}-3 \times 10^4$	$3 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	or $0.56, 1.4 \text{ J} \cdot \text{cm}^{-2}$, whichever is lower 1-mm limiting aperture
0.303	$10^{-2}-3 \times 10^4$	$4 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.304	$10^{-2}-3 \times 10^4$	$6 \times 10^{-3} \text{ J} \cdot \text{cm}^{-2}$	
0.305	$10^{-2}-3 \times 10^4$	$1.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.306	$10^{-2}-3 \times 10^4$	$1.6 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.307	$10^{-2}-3 \times 10^4$	$2.5 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.308	$10^{-2}-3 \times 10^4$	$4.0 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.309	$10^{-2}-3 \times 10^4$	$6.3 \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	
0.310	$10^{-2}-3 \times 10^4$	$1.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.311	$10^{-2}-3 \times 10^4$	$1.6 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.312	$10^{-2}-3 \times 10^4$	$2.5 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.313	$10^{-2}-3 \times 10^4$	$4.0 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.314	$10^{-2}-3 \times 10^4$	$6.3 \times 10^{-1} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^{-9}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10-10^3$	$1 \text{ J} \cdot \text{cm}^{-2}$	
0.315-0.400	$10^3-3 \times 10^4$	$1 \times 10^{-3} \text{ W} \cdot \text{cm}^{-2}$	
Visible and Near Infrared			
0.400-1.400	$10^{-9}-10^{-7}$	$2 C_A \times 10^{-2} \text{ J} \cdot \text{cm}^{-2}$	1-mm limiting aperture
	$10^{-7}-10$	$1.1 C_A t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
	$10-3 \times 10^4$	$0.2 C_A W \cdot \text{cm}^{-2}$	
Far Infrared			
$1.4-10^3$	$10^{-9}-10^{-7}$	$10^{-2} \text{ J} \cdot \text{cm}^{-2}$	1-mm limiting aperture for 1.4 to 100 μm 11-mm limiting aperture for 0.1 to 1 mm
	$10^{-7}-10$	$0.56 t^{1/4} \text{ J} \cdot \text{cm}^{-2}$	
	>10	$0.1 W \cdot \text{cm}^{-2}$	
1.54	10^{-8} to 10^{-6}	$10 \text{ J} \cdot \text{cm}^{-2}$	

Reference: 383, Table 7 With Updates

Figure 5.7.3.2.1-6 Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser Beam

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Laser Type	Primary Wavelength (nm)	Exposure Limit	
		Eye	Skin
Helium-Cadmium Argon	441.6 488/514.5	a) $2.5 \text{ mW} \cdot \text{cm}^{-2}$ for 0.25 s b) $10 \text{ mJ} \cdot \text{cm}^{-2}$ for 10 to 10^4 s c) $1 \mu\text{W} \cdot \text{cm}^{-2}$ for $t > 10^4 \text{ s}$	$0.2 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$
Helium-Neon	632.8	a) $2.5 \text{ mW} \cdot \text{cm}^{-2}$ for 0.25 s b) $10 \text{ mJ} \cdot \text{cm}^{-2}$ for 10 s c) $170 \text{ mJ} \cdot \text{cm}^{-2}$ for $t > 453 \text{ s}$ d) $17 \mu\text{W} \cdot \text{cm}^{-2}$ for $t > 10^4 \text{ s}$	$0.2 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$
Krypton	647	a) $2.5 \text{ mW} \cdot \text{cm}^{-2}$ for 0.25 s b) $10 \text{ mJ} \cdot \text{cm}^{-2}$ for 10 s c) $280 \text{ mJ} \cdot \text{cm}^{-2}$ for $t > 871 \text{ s}$ d) $28 \mu\text{W} \cdot \text{cm}^{-2}$ for $t > 10^4 \text{ s}$	$0.2 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$
Neodymium: YAG Gallium-Arsenide at room temp	1,064 905	$1.6 \text{ mW} \cdot \text{cm}^{-2}$ for $t > 1000 \text{ s}$ $0.8 \text{ mW} \cdot \text{cm}^{-2}$ for $t > 1000 \text{ s}$	$1.0 \text{ W} \cdot \text{cm}^{-2}$ $0.5 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$
Helium-Cadmium Nitrogen	325 337.1	$1 \text{ J} \cdot \text{cm}^{-2}$ for 10 to $3 \times 10^4 \text{ s}$	a) $1 \text{ J} \cdot \text{cm}^{-2}$ for 10 to 1000 s b) $1 \text{ mW} \cdot \text{cm}^{-2}$ for $t > 1000 \text{ s}$
Carbon-dioxide (and other lasers 1.4 μm to 1000 μm)	10,600	$0.1 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$	$0.1 \text{ W} \cdot \text{cm}^{-2}$ for $t > 10 \text{ s}$

Reference: 383, Table A3

Figure 5.7.3.2.1-7 Intrabeam MPE for the Eye and Skin for Selected CW Lasers

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3. Actinic UV Spectrum (200-315 nm) Radiation Exposure Limits - (The following UV exposure limits are contained in ACGIH standards). The Threshold Limit Values (TLV) for radiant exposure incident upon unprotected skin to eye within the 8-hour period are given in Figure 5.7.3.2.1-8. The maximum exposure durations to broadband actinic UV sources are given in Figure 5.7.3.2.1-9.

4. Broad-Band Optical Sources - The weighting functions listed in Figure 5.7.3.2.1-10 shall apply in determining broad-band optical exposure limits. (See ACGIH for formulae needed to calculate exposure times).

5.7.3.2.2 Non-Ionizing Radiation Protection Design Requirements

The following design requirements shall be implemented to protect crewmembers against non-ionizing radiation.

a. Safety Guidelines - Systems employing lasers will be designed and operated in accordance with the ANSI Standard Z136.1-1986 except where the unique environment or mission clearly makes it unreasonable to do so. The hazard analysis for a system will specifically address any instance where it does not meet the standard.

b. RF and Optical Radiation Monitoring - Based on the identified sources of RF and optical radiation, monitoring and warning systems shall be provided consistent with the potential hazard from each source.

c. Safety plans of RF and Optical Sources - Safety plans for the safe operation of RF and optical radiation sources shall be provided. Based on the mission plans, the possibility of providing automatic power shutoff or the safety-related RF and optical radiation equipment shall be considered.

d. Protective Measures - Procedures and space module equipment shall be provided to enable positive protective measures to be taken to prevent accidental exposures from RF and optical radiation.

e. Personnel Protection Devices - Based on the safety guidelines and the results of the electromagnetic hazards analysis personnel protective device requirements (eyewear, clothing) shall be established and the requisite personnel equipment shall be provided.

5.8 THERMAL ENVIRONMENT

5.8.1 Introduction - N/A

5.8.2 Thermal Environment Design Considerations - N/A

5.8.3 Thermal Environment Design Requirements

Paragraphs 5.8.3.1 and 5.8.3.2 provide the design requirements for spacecraft cabin thermal environments.

5.8.3.1 Temperature, Humidity, and Ventilation Design Requirements

The atmospheric temperature, humidity, and ventilation rates shall meet the requirements in Figure 5.1.3.1-1.

5.8.3.2 Thermal Monitoring and Control Design Requirements

The following requirements shall apply to the monitoring and control of the internal ACRV thermal environment:

a. Monitoring of Thermal Environment - Monitoring of the thermal environment shall be fully automatic. The number, type, and location of temperature sensors and the frequency of monitoring shall be such as to ensure measurement of representative cabin temperature and to allow stable control of those temperatures.

b. Crewmembers shall be provided with the capability to control the flow direction of the ventilation.

Wavelength (nm)	TLV ₂ (mJ/cm ²)	Relative Spectral Effectiveness S _A
200	100	0.03
210	40	0.075
220	25	0.12
230	16	0.19
240	10	0.30
250	7.0	0.43
254	6.0	0.5
260	4.6	0.65
270	3.0	1.0
280	3.4	0.88
290	4.7	0.64
300	10	0.30
305	50	0.06
310	200	0.015
315	1000	0.003

* See Laser TLVs.

Reference: 385, page 106-107

*Figure 5.7.3.2.1-B TLV's for Radiant Exposure of Actinic
UV upon Unprotected Skin or Eye*

See following page for applicable notes

Duration of Exposure Per Day	Effective Irradiance, E _{eff} (μW/cm ²)
8 hrs.....	0.1
4 hrs.....	0.2
2 hrs.....	0.4
1 hr.....	0.8
30 min.....	1.7
15 min.....	3.3
10 min.....	5
5 min.....	10
1 min.....	50
30 sec.....	100
10 sec.....	300
1 sec.....	3,000
0.5 sec.....	6,000
0.1 sec.....	30,000

Reference: 385, page 106-107

Figure 5.7.3.2.1-9 Permissible Ultraviolet Exposures

See following page for applicable notes

Notes for Figures 5.7.3.2.1-8 TLV's for Radiant Exposure of Actinic UV upon Unprotected Skin or Eye
and
5.7.3.2.1-9 Permissible Ultraviolet Exposures

ULTRAVIOLET RADIATION

These Threshold Limit Values (TLVs) refer to ultraviolet radiation in the spectral region between 200 and 400 nm and represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effect. These values for exposure of the eye or the skin apply to ultraviolet radiation from arcs, gas and vapor discharges, fluorescent and incandescent sources, and solar radiation, but do not apply to ultraviolet lasers. These values do not apply to ultraviolet radiation exposure of photosensitive individuals or of individuals concomitantly exposed to photosensitizing agents. ⁽¹⁾ These values should be used as guides in the control of exposure to continuous sources where the exposure duration shall not be less than 0.1 sec.

These values should be used as guides in the control of exposure to ultraviolet sources and should not be regarded as a fine line between safe and dangerous levels.

Recommended Values:

The threshold limit value for occupational exposure to ultraviolet radiation incident upon skin or eye where irradiance values are known and exposure time is controlled are as follows:

1. For the near ultraviolet spectral region (320 to 400 nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW/cm² for periods greater than 10³ seconds (approximately 16 minutes) and for exposure times less than 10³ seconds should not exceed one J/cm².
2. For the actinic ultraviolet spectral region (200-315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Figure 5.7.3.2.1-8 within an 8-hour period.
3. To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

$$E_{\text{eff}} = \int E_{\lambda} S_{\lambda} \Delta\lambda$$

Where:

E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in W/cm² (J/s/cm²)

E_{λ} = spectral irradiance in W/cm²/nm

S_{λ} = relative spectral effectiveness (unitless)

$\Delta\lambda$ = band width in nanometers

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 J/cm² by E_{eff} in W/cm².

See Laser TLVs.

Reference: 385

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Wavelength (nm)	Blue-Light Hazard-Function B_1	Burn Hazard Function R_1
400	0.10	1.0
405	0.20	2.0
410	0.40	4.0
415	0.80	8.0
420	0.90	9.0
425	0.95	9.5
430	0.98	9.8
435	1.0	10.0
440	1.0	10.0
445	0.97	9.7
450	0.94	9.4
455	0.90	9.0
460	0.80	8.0
465	0.70	7.0
470	0.62	6.2
475	0.55	5.5
480	0.45	4.5
485	0.40	4.0
490	0.22	2.2
495	0.16	1.6
500-600	$10^{(450-4)/50}$	1.0
600-700	0.001	1.0
700-1050	NA*	$10^{(700-4)/505}$
1050-1400	NA	0.2

NA = Not applicable.

Reference: 385, page 111

Figure 5.7.3.2.1-10 Spectral Weighting Functions for Assessing Retinal Hazards from Broad-Band Optical Sources

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6.0 CREW SAFETY

6.1 INTRODUCTION - N/A

6.2 GENERAL SAFETY

6.2.1 Introduction - N/A

6.2.2 General Safety Design Considerations - N/A

6.2.3 General Safety Design Requirements

The general safety design shall reflect applicable system and personnel safety factors, including minimization of potential human error in the operation and maintenance of the system.

6.3 MECHANICAL HAZARDS

6.3.1 Introduction - N/A

6.3.2 Mechanical Hazards Design Considerations - N/A

6.3.3 Mechanical Hazards Design Requirements

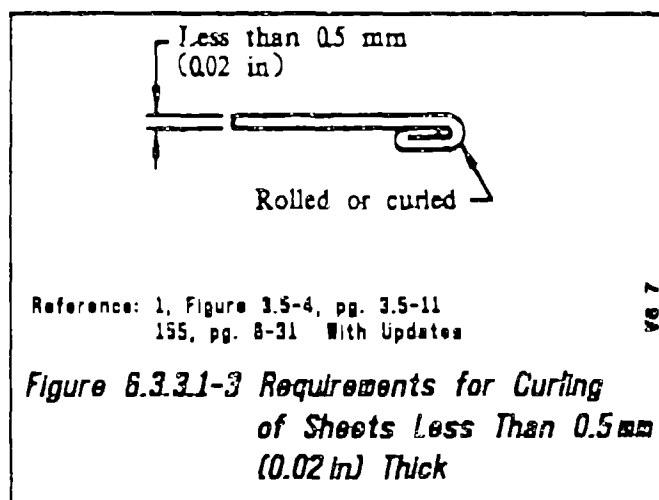
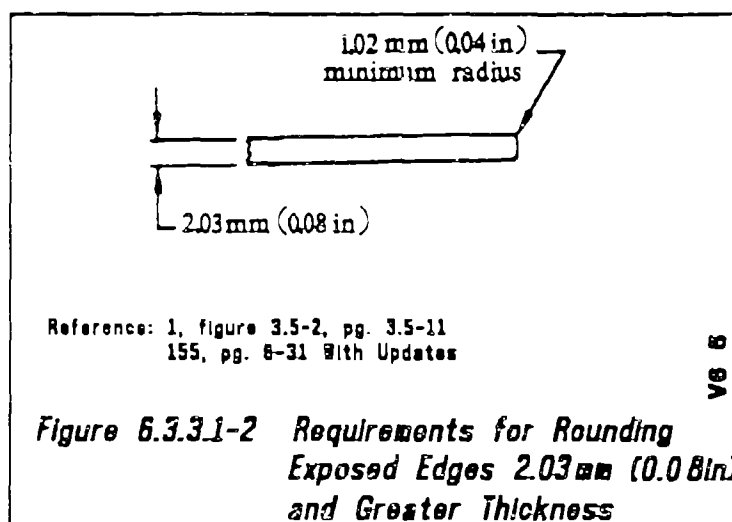
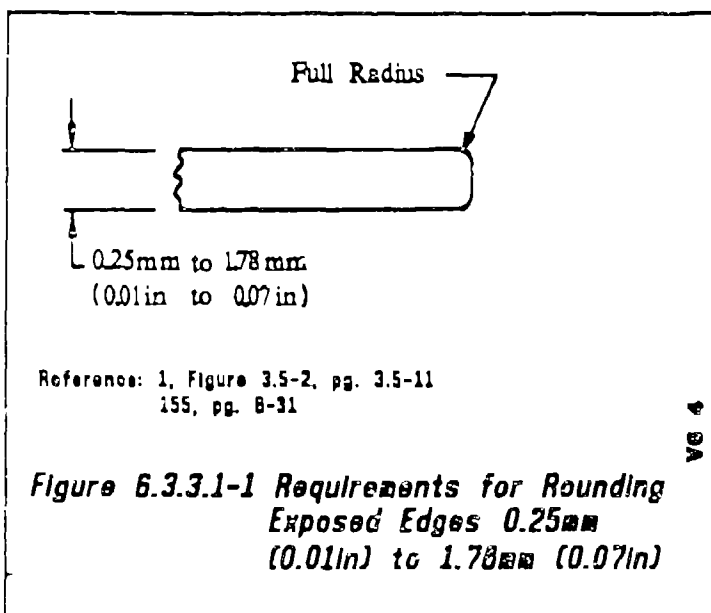
Design requirements for the elimination of burrs, corners, edges, protrusions, pinching, snagging, and cutting for IVA are given in this section:

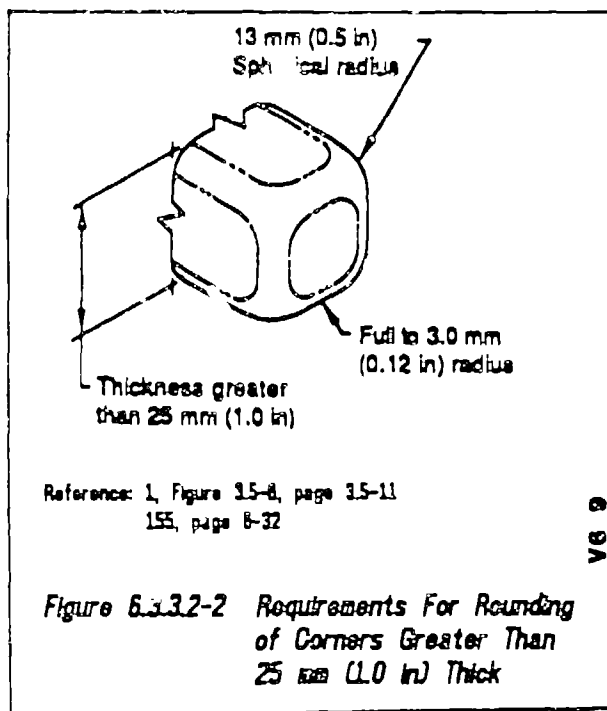
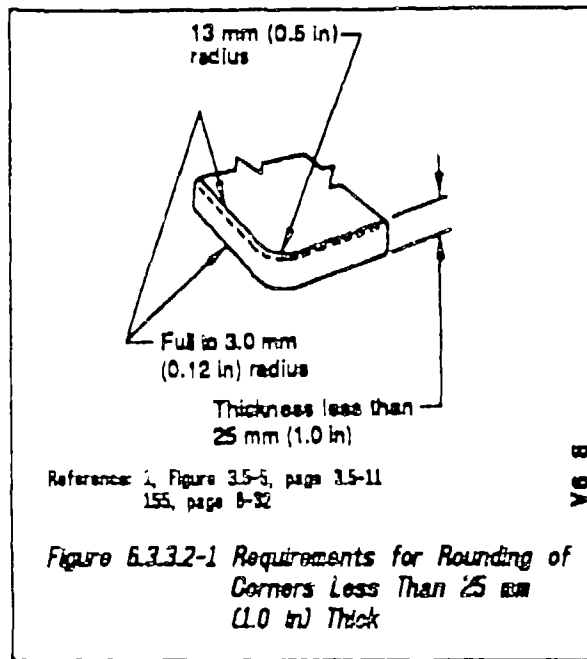
6.3.3.1 Corner and Edge Requirements

- a. Exposed edges 0.25 mm (0.01 in.) to 1.78 mm (0.07 in.) thickness shall be rounded to a full radius as shown in Figure 6.3.3.1-1.
- b. Exposed edges 2.03 mm (0.08 in.) and greater thickness shall be rounded to a minimum radius of 1.02 mm (0.04 in.) as shown in Figure 6.3.3.1-2.
- c. The edges of thin sheets less than 0.5 mm (0.02 in.) thick shall be rolled or curled as shown in Figure 6.3.3.1-3.

6.3.3.2 Exposed Corner Requirements

- a. Exposed corners of materials less than 25 mm (1.0 in.) thick shall be rounded to a minimum radius of 13 mm (0.5 in.), as shown in Figure 6.3.3.2-1.
- b. Exposed corners of materials which exceed 25 mm (1.0 in.) thickness shall be rounded to 13 mm (0.5 in.) spherical radius, as shown in Figure 6.3.3.2-2.





6.3.3.3 Protective Covers on Exposed Protrusions Requirements

Protective covers, cases, or padding shall be used on protrusions or other hazardous objects that cannot be made completely hazard free.

6.3.3.4 Holes Requirements

Holes that are uncovered in the range of 10.0 to 25.0 mm (0.4 to 1.0 in) shall be avoided.

6.3.3.5 Latches Requirements

Latches or similar devices that can pinch fingers shall not be used. A protective guard or cover shall be used where suitable substitutes cannot be found.

6.3.3.6 Screws and Bolts Requirements

Screws or bolts with more than two exposed threads shall be capped to protect against the sharp threads.

6.3.3.7 Securing Pins Requirements

Securing pins in handrails shall be designed to prevent their inadvertently backing out above the handhold surface.

6.3.3.8 Levers, Cranks, Hooks, and Controls Requirements

Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the crewmember or clothing.

6.3.3.9 Burrs Requirements

Exposed surfaces that can be grasped by the bare hand shall be free of burrs.

6.3.3.10 Mechanically Stored Energy Requirements

Care should be taken in the design of mechanical devices capable of storing energy (such as springs, levers, and torsion bars) to avoid injury to the crew.

- a. Safety Features - Where stored energy devices are necessary, safety features such as removal tabs, locks, protective devices, and warning placards shall be provided.
- b. Stored Energy Release - Spring-loaded devices (i.e., bungee restraints) shall provide means for releasing stored energy forces.
- c. Backlash - Stored energy devices shall not generate a backlash.

6.4 ELECTRICAL HAZARDS

6.4.1 Introduction - N/A

6.4.2 Electrical Hazards Design Considerations - N/A

6.4.3 Electrical Hazards Design Requirements

Equipment design shall protect the crewmembers from electrical hazards including those hazards resulting from contact with live conductors and those hazards resulting from leakage current.

6.4.3.1 Chassis Leakage Current

Crewmembers shall not be exposed, by direct or indirect contact with electrically powered equipment, to excessive levels of leakage current as specified within this section.

6.4.3.1.1 Chassis Leakage Current (with frequency components up to 1 kHz)

The available chassis leakage currents for equipment with leakage current frequency components up to one kilohertz shall not exceed the values shown in Figure 6.4.3.1.1-1.

6.4.3.1.2 Chassis Leakage Current (with frequency components up to 1 kHz) Patient Care Equipment - N/A

ENCLOSURE OR CHASSIS					
GROUNDING			DOUBLE INSULATED		
DC	AC	MA	DC	AC	MA
MA	RMS		MA	RMS	
0.700	0.500		0.350	0.250	

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Figure 6.4.3.1.1-1 Nonpatient Equipment Maximum Chassis Leakage Current With Frequency Components Up To 1 Kilohertz

6.4.3.1.3 Chassis Leakage Current (with frequency components above 1 kHz) - Grounded Enclosure/Chassis

The available leakage currents for grounded enclosure/chassis equipment with leakage current frequency components above 1.0 kilohertz shall not exceed the values shown in Figure 6.4.3.1.3-1.

6.4.3.1.4 Chassis Leakage Current (with frequency components above 1 kHz) - Double Insulated Enclosure/Chassis

The available leakage currents for double insulated enclosure/chassis equipment with leakage current frequency components above 1.0 kilohertz shall not exceed 1/2 the values shown in Figure 6.4.3.1.3-1.

6.4.3.2 Crewmember Applied Current Requirements - N/A

MAXIMUM CHASSIS LEAKAGE CURRENT ^{3,4}			RESISTANCE (KILOOHMS) INSERTED IN SERIES WITH GROUNDING CONDUCTOR FOR MEASUREMENT ⁵
DC ma	DC < f ¹ ≤ 1 kHz ma RMS	1 kHz < f ^{1,2} ma RMS	
0.700	0.500	$0.5 \times f_{\text{kHz}} \leq 10.0$	1.000

NOTES:

1. "f" is the frequency component of current contributing to the total chassis leakage current.
2. The maximum leakage current for each frequency component above 1 kHz is individually computed.
3. The sum of the leakage current components within each band of frequencies shall not exceed the maximum leakage currents shown for that band of frequencies.
4. The sum of the three bands of frequency components is the total chassis leakage current and shall not exceed 10.0 milliamperes.
5. A method for determining the chassis leakage current is to use a spectrum analyzer to measure the voltage developed across a resistance inserted in series with the grounding conductor. A frequency's contribution to total leakage current (milliamperes) is then computed as the frequency's voltage (volts) measured across this resistance in series with the ground conductor divided by the resistance (kilohms) in series with the ground conductor.

Figure 6.4.3.1.3-1 Grounded Enclosure/Chassis Maximum Leakage Current With Frequency Components Over One Kilohertz

6.4.3.3 Crewmember Protection Requirements**6.4.3.3.1 Grounding Requirements**

All electrically powered equipment external, non-isolated metal parts subject to user contact shall be at ground potential. A permanent grounding means shall be provided to facilitate the connection of metal parts to ground prior to the connection of any electrical signals or power. A permanent grounding means shall be provided to facilitate the removal of all electrical signals and power prior to the removal of metal parts from ground. Static and safety grounds shall not be used to complete electrical circuits.

6.4.3.3.1.1 Hinged Or Slide Mounted Panels and Doors Grounding

Hinges or slides shall not be used for grounding paths.

6.4.3.3.2 Protective Covers And Termination Points Requirements

Equipment shall provide grounded or nonconductive protective covering for all electrical hardware.

Electrical termination points shall be protected from inadvertent contact by crewmembers, inadvertent contact from foreign objects entering electrical junctions, and moisture accumulation.

6.4.3.3.3 Interlocks Requirements - N/A**6.4.3.3.4 Warning Labels Requirements**

Warning labels shall be provided where potentials are hazardous to crewmembers.

6.4.3.3.5 Warning Labels Plus Recessed Connectors Requirements - N/A**6.4.3.3.6 Plugs and Receptacles Requirements**

a. Plugs and receptacles (connectors) shall be selected and applied such that they cannot be mismatched or cross-connected in the intended system as well as adjacent systems. Although required, the use of identification alone is not sufficient.

b. Connectors shall be selected and applied such that they have sufficient mechanical protection to prevent inadvertent crewmember contact with exposed electrical contacts.

c. Where crewmember connector mating and demating are anticipated, connectors shall be specifically designed and approved for mating and demating in the existing environment under the loads being carried, or connectors shall not be mated or demated until voltages have been removed from the powered side(s) of the connectors.

d. Where crewmember connector mating and demating are anticipated, the design shall provide sufficient room such as to allow connector mating and demating without injury to the crewmember or damage to the connector or surrounding connectors or components.

e. Mechanical strain, such as pull, push, or twist, shall be avoided from being transmitted to electrical junctions, where the strain is static or is imposed by service conditions.

f. Connectors which are mounted to a surface and require a twisting motion by a crewmember to mate or demate shall be positively keyed or pinned to their mounting surface.

6.4.3.3.7 Insulation Requirements

All materials shall meet the following requirements:

- a. All exposed electrical conductors shall be insulated utilizing approved insulating materials.
- b. The crew shall be protected from electrical hazards when performing maintenance on equipment with exposed electrical potentials.

6.4.3.3.8 Power Cords Requirements

Battery powered portable equipment shall be double insulated. Non-battery powered portable equipment shall incorporate a three-wire power cord with one wire at ground potential. A system of double insulation or its equivalent, when approved by the procuring agency, may be used without a ground wire.

6.4.3.3.9 Moisture/Fungus Growth Protection Requirements

Equipment shall be designed so that moisture collection or fungus growth will not present a safety hazard to the crew.

6.4.3.3.10 Static Discharge Protection Requirements

Equipment shall be designed so that the crewmembers are protected from static charge buildup.

6.4.3.3.11 Spacing Between Connectors Requirements

Equipment shall be designed so that a connector installation/removal tool will not make contact between the adjacent connectors.

6.4.3.3.12 Bioinstrumentation System Shock Protection Requirements - N/A

6.4.3.3.13 Electrical Bonding

On-orbit electrical bonding shall prevent injury to crewmembers due to discharges (static, plasma, etc.), induced RF voltages, internal power-faulted equipment, and accidental short circuits.

6.4.3.3.14 Electrical Shielding - N/A

6.4.3.3.15 Overload Protection

- a. The functioning of an overload protective device shall not result in a fire, electrical shock, or crewmember injury.
- b. An overload protective device shall not be accessible without opening a door or cover, except that the operating handle or operating button of a circuit breaker, the cap of an extractor-type fuseholder, and similar parts may project outside the enclosure.
- c. The arrangement of extractor-type fuseholders shall be such that the fuse shall not be positively held or gripped by any part of the fuseholder while energized parts are exposed at any time during replacement. The load shall be connected to the fuseholder terminal that terminates the removable cap assembly.
- d. Overload protection (fuses and circuit breakers) intended to be replaced or physically reset shall be located where they can be seen and replaced or reset without removing other components.
- e. Each overload protector (fuses and circuit breakers) shall be readily identified for its proper value.

6.4.3.3.16 Batteries

Intravehicular batteries shall be located so that they can be easily replaced without special equipment. Polarity of the battery terminals shall be prominently marked.

6.4.3.3.17 Combustible Materials - N/A

6.4.3.3.18 Cable and Wiring - N/A

6.4.3.3.19 Mechanical Assembly

A switch, fuseholder, lampholder, attachment plug receptacle, or other energized component that is handled by a crewmember shall not rely on friction alone to prevent turning in its mounting panel.

6.4.3.3.20 Switches/Controls

Switches/controls shall be designed such as to prevent hazardous unexpected manual or automatic operation. Switches/controls which provide automatic starting after an overload initiated shutdown shall not be employed.

6.4.3.3.21 Electronically Produced Radiation - N/A

6.4.3.3.22 Power Driven Equipment And Controls

If a risk of injury to a crewmember can result from the motion of power driven equipment:

- a. The controls for that mechanism shall be of a reversible type and shall not continue operation of the moving part in the same direction when a switch readily accessible to that crewmember is activated to initiate operation in the other direction, or
- b. The power driven equipment shall be mechanically constructed such that the injurious forces are immediately removed by activation of a switch readily accessible to that crewmember.

6.5 TOUCH TEMPERATURE

6.5.1 Introduction - N/A

6.5.2 Touch Temperature Design Considerations - N/A

6.5.3 Touch Temperature Design Requirements

Surface touch temperature design requirements for minimizing crewmember discomfort and injury are as follows:

- a. The design goal for the maximum surface temperatures which can come into contact with bare skin shall be 40°C (104°F).
- b. The maximum allowable surface temperature for continuous contact with bare skin shall be 45°C (113°F).
- c. Incidental or momentary bare skin contact with surface temperatures from 46° - 49°C (114° - 120°F) is permissible. Warning labels shall be provided to alert crewmembers to these excessive temperature levels. Guards or insulation shall be provided to prevent crewmember contact with surface temperatures in excess of 49°C (120°F). Where contact with surfaces above this limit is required, adequate warning labels and protective equipment are required.
- d. For surfaces that must be touched with bare skin, the minimum temperature shall not be below 4°C (39°F). Where contact with surfaces below this limit is required, adequate warning labels and protective equipment are required.

6.6 FIRE PROTECTION AND CONTROL

6.6.1 Introduction - N/A

6.6.2 Fire Protection and Control Design Considerations - N/A

6.6.3 Fire Protection and Control Design Requirements

Fire protection and control design requirements are given below.

6.6.3.1 General Requirements

6.6.3.1.1 Fire Protection System

A fire protection system comprising detection, warning, and extinguishing devices shall be provided during all mission phases.

6.6.3.1.2 Material Selection

Only approved fire-retardant materials shall be used.

6.6.3.2 Detection Requirements

6.6.3.2.1 Detection System Signals

The fire detection system shall provide signals to the vehicle warning system.

6.6.3.2.2 Reset and Self-test

The fire detection system shall have reset and self-test capabilities.

6.6.3.2.3 Sensor Replacement

All sensors shall be replaceable and accessible.

6.6.3.3 Warning System Requirements

Warning - General requirements for the fire warning system are as follows:

- a. The caution and warning system shall include a fire warning system to alert the crew in case of a fire.
- b. The fire warning system shall be capable of operating independently.
- c. Warnings shall be both visual and auditory to provide maximum information to the crew for timely action.
- d. The visual fire warning display shall be aviation red in accordance with MIL-STD-25050.

6.6.3.4 Extinguishing Requirements

- a. Portable fire extinguishers shall be provided to contain and extinguish all fires in open and enclosed areas.
- b. The design of the portable fire extinguishers and interior components shall provide for access to enclosed areas with the extinguisher or extinguishing agent via fire holes or other functionally equivalent design solution.
- c. The design of the portable fire extinguisher shall provide for single handed use.
- d. Chemical agents used for fire extinguishing shall be compatible with toxicity requirements for the ACRV and the SSF.
- e. Design of the vehicle and its components shall provide for rapid access with fire fighting equipment.

7.0 HEALTH MANAGEMENT

7.1 INTRODUCTION - N/A

7.2 PREVENTIVE CARE

7.2.1 Introduction - N/A

7.2.2 Nutrition

7.2.2.1 Introduction - N/A

7.2.2.2 Nutrition Design Considerations - N/A

7.2.2.3 Nutrition Design Requirements

7.2.2.3.1 Food Design Requirements

- a. Food provisioning - The food shall be shelf stable with a minimum shelf life of 2 years when stored at 21°C (70°F).
- b. Number of meals - One meal per person shall be stored for each eight hours of anticipated occupancy of the ACRV, including orbital loiter time and time on the earth's surface without rescue services.
- c. Weight and volume - Weight of the food shall not exceed 0.3 Kg (0.67 lb) per person and volume shall not exceed 1 liter (0.035 ft³) per person for each eight hours of anticipated ACRV occupancy time.

7.2.2.3.2 Potable Water Design Requirements

7.2.2.3.2.1 Potable Water Quality Design Requirements - N/A

7.2.2.3.2.2 Potable Water Quantity Design Requirements

The supply of available water for drinking and rehydration of food shall be a minimum of 0.25 Kg (2.1 lbs) per person for each eight hours of anticipated ACRV occupancy time, including orbital loiter time and time on the earth's surface without rescue services. An additional 1 Kg (2.2 lbs) of water and 8 one gram salt tablets shall be provided for each person for the purpose of supporting re-entry fluid loss countermeasures.

7.2.2.3.2.3 Potable Water Temperature Design Requirements

Drinking Water shall be prevented from freezing.

7.2.3 Reduced Gravity Countermeasures

7.2.3.1 Introduction - N/A

7.2.3.2 Reduced Gravity Countermeasures Design Considerations - N/A

7.2.3.3 Exercise Countermeasures - N/A

7.2.3.4 Nonexercise Countermeasures

7.2.3.4.1 Introduction - N/A

7.2.3.4.2 Nonexercise Countermeasures Design Considerations - N/A

7.2.3.4.3 Nonexercise Countermeasures Design Requirements

Pharmacological methods, including oral rehydration, shall be provided to increase the body's total fluid volume. These countermeasures shall be completed prior to entry.

7.2.4 Sleep - N/A

7.2.5 Personal Hygiene - N/A

7.2.6 Pre/Post-Mission Health Management - N/A

7.2.7 Health Monitoring

7.2.7.1 Introduction - N/A

7.2.7.2 Routine Health Monitoring Design Considerations - N/A

7.2.7.3 Routine Health Monitoring Design Requirements

7.2.7.3.1 Routine Crew Health Monitoring Design Requirements - N/A

7.2.7.3.2 Water Supply Monitoring Design Requirements - N/A

7.2.7.3.3 Environmental Monitoring Design Requirements

Environmental monitoring shall be accommodated as necessary to maintain crew health.

7.3 MEDICAL CARE

7.3.1 Introduction - N/A

7.3.2 Medical Care Design Considerations - N/A

7.3.3 Medical Care Design Requirements

The ACRV shall provide first aid and survival equipment appropriate to the landing environment.

7.4 CREW SURVIVAL

7.4.1 Introduction - N/A

7.4.2 Crew Survival Design Considerations - N/A

7.4.3 Crew Survival Design Requirements

- a. The ACRV shall be designed to preclude hazard to the crew or prevent egress from the crashed vehicle in the event of off nominal landing.
- b. Equipment and attachment structures inside the crew compartment (including fittings and fasteners) shall be designed for off nominal landing loads specified below in Figure 7.4.3-1.

7.4.3.1 Medical Kit Design Requirements

The ACRV shall provide an emergency medical kit listed in Figure 7.4.3.1-1.

7.4.3.2 Crew Survival Kit Design Requirements

The ACRV shall provide the survival equipment listed in Figure 7.4.3.2-1.

N _x	N _y	N _z
20.0	3.3	10.0
-3.3	-3.3	-4.4

g's

Note: These load factors shall act independently and the longitudinal load factor shall be directed within 20° of the longitudinal axis.

Figure 7.4.3-1 Ultimate Inertia Load Factors

Airway		
Oral airway	Min. of 4	
Tracheal tube w/stylet	Min. of 2	
Laryngoscope	1	
Pertrach Kit	1	
Comox resuscitator	1	
Ambu Bag		
Antiseptics		
Alcohol wipes		
Bandages		
Ace Bandage		
Bandaids		
Kling		
Sponges		
Telfa pads (4 X 4s)		
Wound pack		
Burns		
Silvadene cream (silver sulfadiazine)		
Decongestants		
Afrin nasal spray	1 bottle	
Diagnostic Equipment		
Blood Pressure cuff		
Stethoscope		
Eye Treatment		
Tearisol eye drops (artificial tears)		
Motion Sickness		
Phenergan, oral		
Scop/Dex		
Pain Medications		
Ascriptin (aspirin)		
Tylenol (acetaminophen w/codeine)		
Miscellaneous		
Scissors		
Tweezers		
Tape (generic adhesive - medical)		
Steri-Strip skin closure		
Penlight		

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Figure 7.4.3.1-1 ACRY Emergency Medical Kit

ITEM	BOTH	LAND ONLY	WATER ONLY
Water (2 liter/person)	2 liter/person		
Day/night flare	2		
Thermal blanket (large)	2		
Chem lights	10		
Strobe light	1		
Pen gun flares	1 gun, 14 flares		
First aid kit	1		
PRC-112 radio (kit)	1		
Signal mirror	1		
Knife	1		
Sunscreen	1		
Compass	1		
Whistle	1		
Penlight	2		
SARSAT Beacon	1		
Motion sickness pills			In first aid kit
Sea dye marker			4
Life raft			1 crew raft
Matches		10	
Fire starter kit		2	

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Figure 7.4.3.2-1 ACRY Proposed 24 Hour Survival Kit (Post-landing)

8.0 ARCHITECTURE

8.1 INTRODUCTION - N/A

8.2 OVERALL ARCHITECTURAL CONSIDERATIONS AND REQUIREMENTS - N/A

8.3 CREW STATION ADJACENCIES - N/A

8.4 COMPARTMENT AND CREW STATION ORIENTATION - N/A

8.5 LOCATION CODING

8.5.1 Introduction - N/A

8.5.2 Location Coding Design Considerations - N/A

8.5.3 Location Coding Design Requirements

8.5.3.1 Alphanumeric Coding Design Requirements

An alphanumeric coding system shall be established for the Assured Crew Return Vehicle. The system shall have the following characteristics:

- a. Ease of Use - The coding system shall be simple to use, communicate, and memorize.
- b. ACRV Consistency - The coding system shall be consistent throughout the ACRV and attached components and the Space Station Freedom. The system shall be consistent for both interior and exterior locations.
- c. User Consistency - The coding system shall be consistent for all personnel who use and maintain the ACRV. The system shall be compatible with (if not identical to) design engineering location systems.
- d. Flexibility - The coding system shall be flexible to allow adaptation to ACRV design changes and reconfiguration.

8.5.3.2 Directional Designation Design Requirements - N/A

8.5.3.3 Location & Orientation By Color Coding Design Requirements

The following requirements apply to the use of color for location and orientation coding:

- a. Colors - The colors selected for coding shall be consistent with the requirements in Paragraph 9.5.3.2.1, Color Coding.
- b. Consistency - If color is used for location coding purposes, the colors shall have the same operational significance throughout the ACRV and shall be consistent in application.

8.5.3.4 Location Coding With Placards Design Requirements

An ACRV shall have markings to provide the crew with equipment and compartment identification, and directional and spatial orientation information. The specific requirements for location coding placards are as follows:

- a. Map - A map of location codes shall be provided at the entrances to areas where the coding scheme is not obvious to the crewmember or for areas in which there is a significant amount of preparation activity such as stowage, adjustment, or maintenance of items.
- b. Placards on Movable Items - Movable items and their stowage locations shall be labeled as necessary to ensure the item is returned to the proper location after use.
- c. Directional Designation - A visual cue shall be provided to allow the crewmember to quickly adjust to the orientation of the crew station.
- d. Markings - Label and placard format and markings shall meet the requirements in Paragraph 9.5, Labeling and Coding.

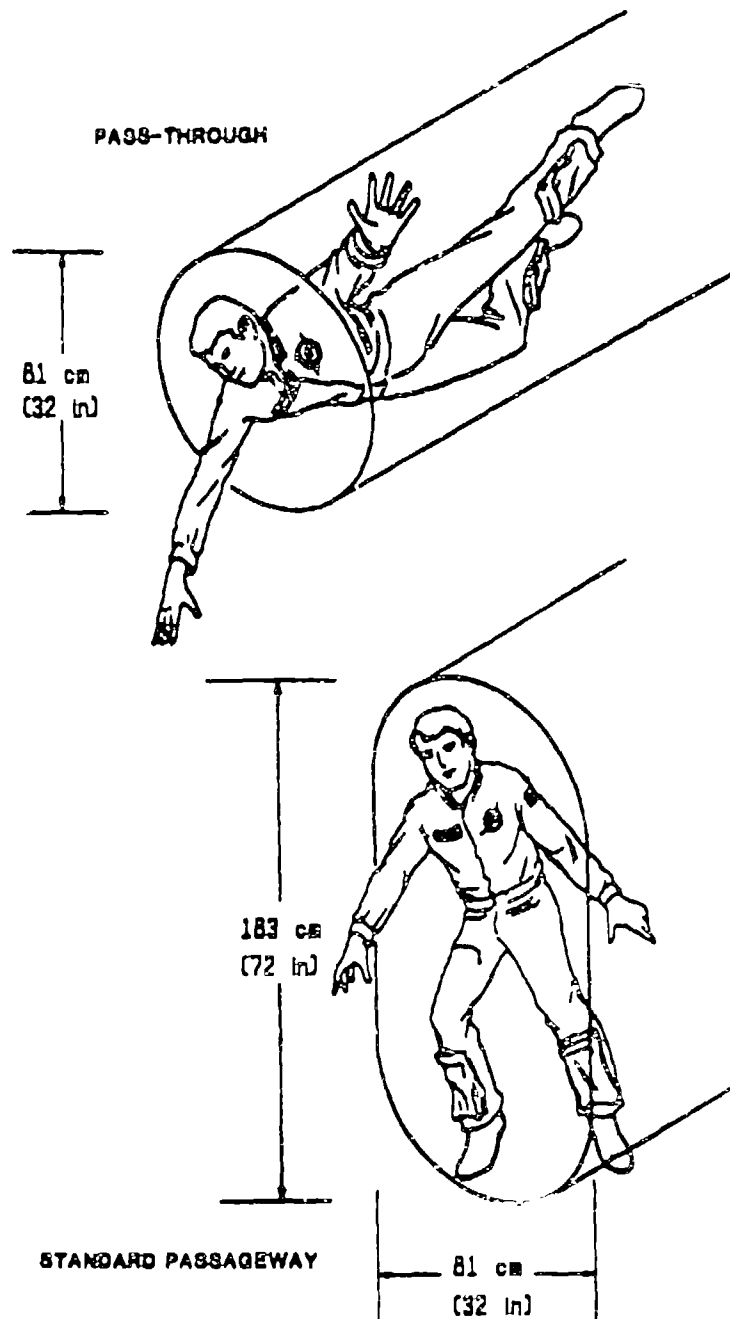
8.6 ENVELOPE GEOMETRY FOR CREW FUNCTIONS - N/A**8.7 TRAFFIC FLOW - N/A****8.8 TRANSLATION PATHS****8.8.1 Introduction - N/A****8.8.2 Translation Path Design Considerations - N/A****8.8.3 Translation Path Design Requirements****8.8.3.1 Minimum Translation Path Dimensions Design Requirements**

Minimum cross sectional dimensions of translation paths for one crewmember in light clothing are shown in Figure 8.8.3.1-1 and Figure 8.8.3.1-2. Translation path access to seating shall consider body dimensions specified in 3.3.1.3-1.

8.8.3.2 Clearances Design Requirements

In addition to the minimum dimensions given in Paragraph 8.8.3.1, translation paths shall be designed to provide the following clearances:

- a. Equipment or Package Clearances - Translation paths through which equipment or packages must be transported shall allow sufficient clearances for the safety of both the equipment and the ACRV.



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Figure 8.8.3.1-1 Minimum Translation Path Dimensions for Microgravity, One Crew Member in Light Clothing

TBD

*Figure 8.8.3.1-2 Minimum Transition Path
Dimensions for 1-G, One
Crewmember in Light Clothing*

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b. Orientation and Directional Change Clearances - Additional clearance volume shall be provided as required for the crewmember to make changes in orientation and/or direction of travel.

c. Ill or Injured Crew Ingress/Egress Clearance - TBD

8.8.3.3 Translation Path Obstructions and Hazards Design Requirements

The following translation path obstructions and hazards shall be minimized:

a. Injury or Damage From Translation Path Surface - Design translation paths to minimize the possibility of injury to the crewmember or damage to transferred equipment or the facility during translation.

b. Damage to Nearby Equipment - Equipment located near traffic paths shall be designed to withstand the abuse of crew translation (for example, equipment may be used as a grasp surface or a surface from which crewmembers propel themselves).

c. Obstructions and Entanglements - The translation path and surrounding areas shall be designed to minimize the possibility of entanglement of translating crewmembers or equipment with loose objects such as restraints, cables, hoses, wires, etc.

8.9 MOBILITY AIDS AND RESTRAINTS ARCHITECTURAL INTEGRATION

8.9.1 Introduction - N/A

8.9.2 Mobility Aids & Restraints Integration Design Considerations - N/A

8.9.3 Mobility Aids and Restraints Design Requirements

8.9.3.1 IVA Mobility Aid Integration Design Requirements

Mobility aids shall be located along translation paths as necessary for crewmembers to initiate translation movement, terminate translation movement, or change direction or speed.

8.9.3.2 IVA Restraint Integration Design Requirements

The following are requirements for integration of fixed IVA restraints into the ACRV architecture:

- a. Areas Where High Force Application is Required - Restraints shall be provided where crewmembers are expected to exert forces that cause the body to move in reaction, thereby degrading task performance.
- b. Medical Facility - At least one ACRV couch shall be configured to accommodate patient restraints from the Space Station Freedom Health Maintenance Facility. Appropriate restraint shall be provided to allow access to the ill or injured patient.
- c. Noninterference - Restraints shall be located so as not to restrict or interfere with crew operations.

8.10 HATCHES AND DOORS

8.10.1 Introduction - N/A

8.10.2 Hatch and Door Design Considerations - N/A

8.10.3 Hatch and Door Design Requirements

8.10.3.1 Location Design Requirements - TBD

8.10.3.2 Pressure Hatch Indicator/Visual Display Design Requirements

Pressure hatch covers shall have the following visual displays and indicators:

- a. Visual Inspection of Hatch Security - A means shall be provided on both sides of the pressure hatch for visual safety check to ensure that it has been secured properly.
- b. Status Display - Pressure differentials and hatch operational status displays shall be provided as necessary for safety at appropriate space module command and control center(s).
- c. Pressure Difference Indicators - Pressure hatches shall have pressure difference indicators visible on both sides of the hatch.
- d. Operating Instructions - All pressure hatches shall display operating procedures on both sides of the hatch.

8.10.3.3 Opening and Closing Mechanisms Design Requirements

The hatch and door opening and closing mechanisms shall meet the following design requirements:

- a. Special Tools - The ACRV design shall allow the crew access hatches to be manually opened from the interior and exterior without the use of tools.
- b. Emergency Operation - Latching mechanisms shall provide for emergency operation in case of a latching system failure.
- c. Operation From Both Sides - Hatches shall be capable of being operated, locked, and unlocked from either side.
- d. Interlock - Pressure hatches shall be prevented from unlatching prior to pressure equalization.
- e. Single Crewmember Operation - Hatches shall be capable of being operated by one crewmember.
- f. Emergency Closing - Hatches and doors shall allow crewmembers to close covers with or against pressure differentials, for the worst case pressure differential anticipated.

8.10.3.4 Operating Forces Design Requirements

Hatch and door cover operating forces shall meet the following requirements:

- a. Latch Operations - The force required to operate door and hatch latches shall not exceed the strength of the weakest of the defined crewmember as defined in section 4.10, Effects of Deconditioning.
- b. Restraints - Restraints shall be provided as necessary to counteract body movement when opening or closing the hatch.

8.10.3.5 Minimum Size Design Requirements

The hatch or door opening shall be free of protrusions which might injure personnel or damage equipment. The minimum size of these openings shall accommodate passage of the largest replaceable module or crewmember (whichever is larger) intended to pass through the opening.

8.10.3.6 Door and Hatch Shape Design Requirements

Doors and pressure-sealing hatches shall be shaped such that they can pass through the opening into which they are designed to fit/seal to allow for removal, maintenance, repair, relocation, etc.

8.11 VIEWING - N/A

8.12 INTERIOR DESIGN AND DECOR

8.12.1 Introduction - N/A

8.12.2 Interior Design and Decor Design Considerations - N/A

8.12.3 Interior Design and Decor Design Requirements

The following are requirements for the interior design and decor of the ACRV:

8.12.3.1 Aesthetic and Psychological Requirements - N/A

8.12.3.2 Decor Flexibility - N/A

8.12.3.3 Color Selection

The use of dark (low brightness) or saturated colors shall be restricted to small areas, (e.g., handrails, display frames, etc.).

8.12.3.4 Decor Cleaning and Maintenance

All surfaces shall be easily cleaned and maintained.

8.12.3.5 Decor Durability

Decor materials shall be resistant to abrasion, scratching, and corrosive contaminants such as spilled chemicals, grease, body excretions, fungi, moisture, direct sunlight, ozone, and airborne particles.

8.12.3.6 Safety

The decor shall not be hazardous to the crew. Potential hazards include flammability, offgassing of toxic fumes, and mechanical hazards.

8.13 LIGHTING

8.13.1 Introduction - N/A

8.13.2 Lighting Design Considerations - N/A

8.13.3 Lighting Design Requirements

8.13.3.1 Illumination Level Design Requirements

8.13.3.1.1 General Interior Illumination Levels Design Requirements

The interior general illumination of the Assured Crew Return Vehicle shall be a minimum of 108 lux (10 foot-candles) of white light.

8.13.3.1.2 Illumination For Specific Tasks Design Requirements

The lighting level shall be measured on the primary work surfaces visual interface or 30 inches above the floor where appropriate. Measurement shall be taken at 80% of maximum power.

Specific IVA task lighting requirements are defined in Figure 8.13.3.1.2-1 which also defines illumination levels for workstations.

8.13.3.1.3 Illumination Levels of Sleeping Areas Design Requirements - N/A

AREA or TASK	Lux	(Ft. C.)
GENERAL	54	(5)
PASSAGEWAYS	32	(3)
Hatches	54	(5)
Handles	54	(5)
Ladders	54	(5)
STOWAGE AREAS	54	(5)
HEALTH MAINTENANCE	215	(20)
WORKSTATION	108	(10)
EMERGENCY LIGHTING	32	(3)

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Reference: 351 With Updates

Note: Levels are measured at the task or 760mm (30 in) above floor. All levels are minimums.

Figure 8.13.3.1.2-1 Space Vehicle Illumination Levels

8.13.3.1.4 Illumination Levels for Dark Adaptation Design Requirements

If maximum dark adaptation is required, provisions shall be made for dimming or extinguishing shall be provided.

When dark adaptation is required for performance of tasks, the following measures shall be taken:

- a. Low Level Lighting - Low level lighting shall be provided for task performance which minimizes loss of dark adaptation.
- b. Protection From Stray Light - Areas requiring low level illumination shall be protected from external light sources. All external windows shall be provided with protective light shields (shades, curtains, etc)

8.13.3.2 Light Distribution Design Requirements

8.13.3.2.1 Glare From Light Sources Design Requirements - N/A

8.13.3.2.2 Reflected Glare Design Requirements - N/A

8.13.3.2.3 Brightness Ratio Design Requirements

The maximum and minimum luminance ratio for any individual surface shall not exceed 20:1.

8.13.3.3 Light Color Design Requirements

The color temperature of the lighting shall be 3800 K or greater.

8.13.3.4 Lighting Fixtures and Controls Design Requirements

The following design requirements apply to lighting fixtures and their controls:

- a. Emergency Lights - An independent, self-energizing illumination system shall be provided that will be automatically activated in the event of a major primary power failure or main lighting circuit malfunction resulting in circuit breaker interruption.
- b. Controls - Lighting controls shall meet the following requirements
 - 1. Required controls - Each light fixture shall have its own control. Controls for artificial illumination at the workstation shall be located within the reach envelope for the operator at the display/control panel or workstation that is affected.
 - 2. Control identification - Lighting controls shall be illuminated in areas that are frequently darkened.
 - 3. Variability - Dimmer controls shall be provided (either discrete or continuous) when required for mission requirements.

c. Flicker - Light sources shall not have a perceptible flicker.

d. Fixture Protection - The following protective measures shall be incorporated into lighting fixtures:

1. Protection from crew - Light sources shall be protected from damage by crew activity.
2. Hot surfaces - Provide protective covers on lighting fixtures whose surface temperature exceeds the maximum allowable temperatures given in Paragraph 6.5.3 b.
3. Bulb or Lens Breakage - Provisions shall be incorporated into all light fixtures to contain all glass fragments in the case of bulb or lens breakage.
4. Replacement of Bulbs - Provisions shall be incorporated into all light fixtures to allow for replacement of bulbs or luminaires as appropriate without tools and without imposing any hazard to the crew.

e. Portable Lights - Portable lights shall be provided as necessary for illumination of otherwise inaccessible areas or as supplemental lighting.

8.13.3.5 Ambient Medical Lighting Requirements

- a. The light intensity shall be as specified in Figure 8.13.3.1.2-1.
- b. The minimum (contingency) illuminance needed for patient treatment is 215 lux (20 ft. cd.).
- c. The light source shall have a color temperature of 5000 °K.

8.13.3.6 Workstation Illumination Design Requirements

- a. Primary viewing areas (30 to 60 degree visual angle about primary lines of sight) - Maintain a 5:1 ratio.
- b. If workstations are required, provisions shall be made for integral lighting. The lighting shall be dimmable.

9.0 WORKSTATIONS

9.1 INTRODUCTION - N/A

9.2 WORKSTATION LAYOUT

9.2.1 Introduction - N/A

9.2.2 General Workstation Design Factors - N/A

9.2.3 Control/Display Placement and Integration

9.2.3.1 Control/Display Placement and Integration Design Considerations - N/A

9.2.3.2 Control/Display Placement and Integration Design Requirements

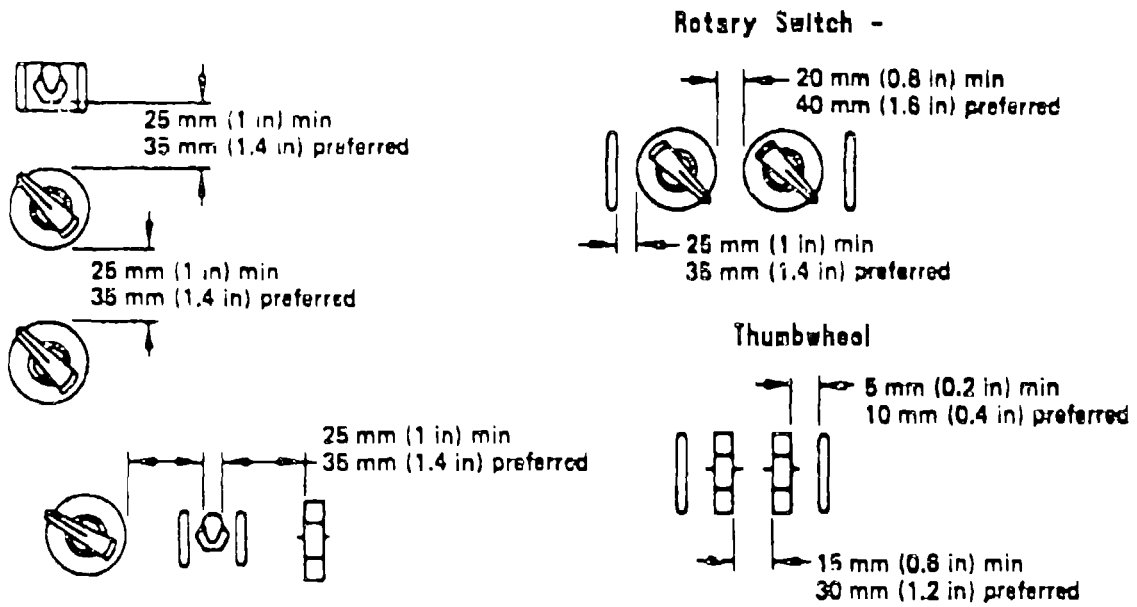
9.2.3.2.1 Control Spacing Design Requirements

Minimum and preferred spacing for different types of controls are shown in Figure 9.2.3.2.1-1 for the ungloved condition.

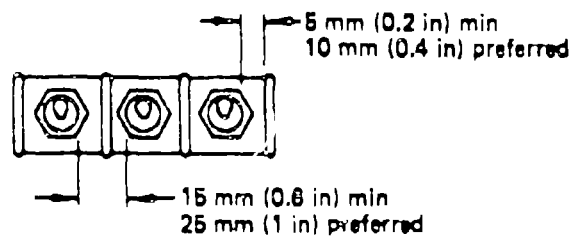
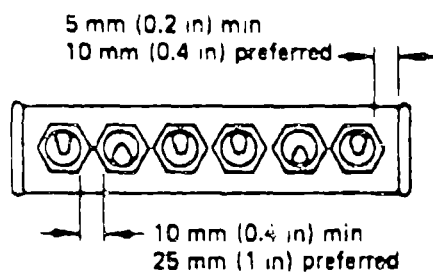
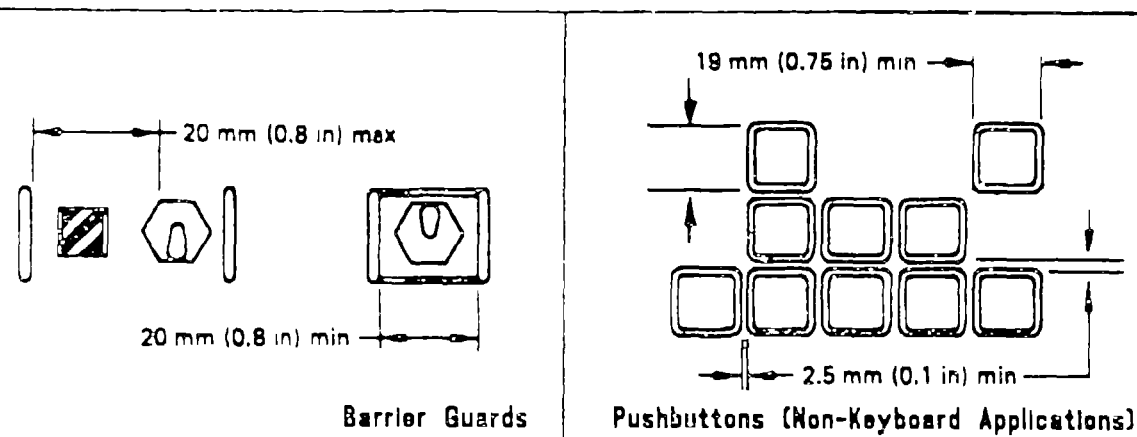
9.2.3.2.2 Display Readability Design Requirements

Displays shall be located and designed so that they may be read, to the degree of accuracy required, by personnel in the normal operating or servicing positions without requiring the operator to assume an uncomfortable, awkward, or unsafe position. Requirements for designing readable displays are provided below.

- a. Accessibility - Displays shall be visually accessible.
- b. Parallax Error - Displays shall be located so that they can be read from the design eye point with no discernible parallax.
- c. Orientation - Display faces shall be perpendicular to the operator's line-of-sight whenever feasible. The angle between the line-of-sight and the normal to the display shall always be less than 30 degrees.
- d. Simultaneous Use - A visual display that must be monitored concurrently with manipulation of a related control shall be located so that it can be read to within required accuracy while adjusting the control.
- e. Display Functionality - Displays shall provide positive and unambiguous indication of system state (e.g., a light indicating "power on", a blinking cursor indicating "ready"). These positive indications shall be used consistently throughout the ACRV.



Rotary Controls



Spacing Required Between Switch Controls

Reference: 1, page 4.9-9

With Updates

Note. See Figure 9.3.3.4.12-1 for Keyboard Layout Dimensions

Figure 9.2.3.2.1-1 Control Spacing Requirements For Ungloved Operation

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9.2.3.2.3 Control/Display Grouping Design Requirements

Requirements for grouping controls and displays are listed below.

a. Functional Grouping - Displays and/or controls that are functionally related shall be located in proximity to one another arranged in functional groups (e.g., power, status, test).

b. Sequential Grouping - When a unique sequence of control actions exists, the controls and/or displays shall be arranged in relation to one another according to their sequence of use. Within a functional group, the sequence shall be from left to right or top to bottom whenever feasible.

c. Logical Flow Grouping - When there is not a unique sequence or functional grouping of control actions, controls and displays shall be arranged in a manner consistent with their logical flow.

If controls are not to be utilized in any specific sequence, then consider arranging them by importance with the most important or frequently used control in the most accessible position.

d. Functional Group Markings - If several functional groupings of displays and controls are placed in close proximity on a control panel, an effective means of discriminating between them shall be provided (e.g., color coding or outlining).

e. Left-to-Right Arrangement - If controls must be arranged in fewer rows than displays, controls affecting the top row of displays shall be positioned at the far left; controls affecting the second row of displays shall be placed immediately to the right of these, etc.

f. Vertical and Horizontal Arrays - If a horizontal row of displays must be associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, etc. However, this type of arrangement shall be avoided whenever possible.

g. Multiple Displays - When the manipulation of one control requires the reading of several displays, the control shall be placed as near as possible to the related displays, but not so as to obscure displays when manipulating the control.

h. Separate Panels - When functionally related controls and displays must be located on separate panels and both panels are mounted at approximately the same angle relative to the operator, the control positions on one panel shall correspond to the associated display positions on the other panel. The two panels shall not be mounted facing each other. Controls and displays on separate panels are discouraged.

9.2.3.2.4 Preferred Control/Display Location Design Requirements

Design requirements for the placement of displays and controls are provided below.

a. Display Location - The most important and frequently used displays shall be located in a privileged position in the optimum visual zone, providing that the integrity of grouping by function and sequence is not compromised. See Figure 9.2.4.2.2-2 for a definition of this zone.

b. **Control Location** - The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings), providing that the integrity of grouping by function and sequence is not compromised.

c. **Multi-G Control Placement** - Special attention shall be paid to the placement of controls which must be used while the crewmember is subject to either prolonged or transitory acceleration forces above 2-G.

1. In general, these controls shall be located so that the operator's limb is always in contact with the control (i.e., no reaching is required).
2. The requirements for movement from one control to another shall be minimized (e.g., use combined controls with several functions mounted on a single shaft).
3. Rotary controls shall be selected in preference to linear controls whenever possible.
4. When linear controls are necessary, they shall be mounted so that the direction of operation is perpendicular to the direction of G-forces.
5. Guidelines to accommodate deconditioned crewmembers are found in section 4.10.

d. **Control/Display Relationships:**

1. The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator.
2. Controls shall be located adjacent to their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

9.2.3.2.5 Consistent Control/Display Placement Design Requirements

Requirements for maintaining consistency in control and display design are provided below.

- a. **Similarity** - The arrangement of functionally similar or identical displays and controls shall be consistent from panel to panel throughout and between systems, equipment, units, and vehicles.
- b. **Mirror Images** - Mirror image arrangements shall not be used for asymmetrical display and control layouts.

9.2.3.2.6 Maintenance Controls/Displays Design Requirements - N/A

9.2.3.2.7 Emergency Control/Display Placement Design Requirements

Requirements for emergency displays and controls are provided below.

- a. **Emergency Control/Display Placement** - Emergency displays and controls shall be located where they can be seen and reached with minimum delay.

b. Computer-Generated Emergency Displays - Emergency information depicted on existing computer-controlled displays shall be sufficiently conspicuous to attract the user's attention consistently.

9.2.3.2.8 Control/Display Movement Compatibility Design Requirements

Requirements for control/display movement compatibility are provided below.

a. Consistency of Movement - Controls shall be selected so that the direction of movements of the control will be consistent with the related movement of an associated display, equipment component, or vehicle.

b. Complex Movement Control - When the vehicle, equipment, or components are capable of motion in more than two dimensions, exception to 9.2.3.2.8 a shall be made to:

1. Maintain consistency with other systems.

2. Maintain a natural association between control and system movements. For example, forward motion of a directional control causes some vehicles to dive or otherwise descend rather than to simply move forward.

c. Conflict Avoidance - When several controls are combined in one control activity, caution shall be exercised to avoid a situation in which similar movement of different controls results in different systems responses (e.g., control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

d. Remote Controls - Where controls are operated at a position remote from the equipment or controlled vehicle, they shall be arranged to facilitate consistency of movement.

e. Movement Direction - When a rotary control and linear display are in the same plane, the part of the control adjacent to the display shall move in the same direction as the moving part of the display.

f. Labeling - When control/display relationships specified herein cannot be adhered to, controls shall be clearly labeled to indicate the direction of control movement required.

g. Time Lag - The time lag between the response of a system to a control input and the display presentation of the response shall be minimized, consistent with safe and efficient system operation. Where such time delay exceeds acceptable limits, the action of the control shall be appropriately modified (by force feedback or other means) to avoid overcontrol. Simple requests for data shall be carried out more rapidly than .5 to 1.0 sec, while changes of entire data pages may be executed in up to 10 sec, depending on the user's expectations and the criticality of the information. If processing requirements result in longer delays, then the system shall acknowledge a control input immediately and provide periodic updates showing the progress of the processing.

9.2.3.2.9 Control/Display Movement Ratio Design Requirements

Requirements for designing the relative movement ratios between controls and displays are provided below.

- a. Adjustment Time - Control/display ratios for continuous adjustment controls shall minimize the total time required to make the desired control movement (i.e., slewing time plus fine adjusting time) consistent with display size, tolerance requirements, viewing distance, and time delays.
- b. Range of Display Movement:
 - 1. When a wide range of display element movement is required, small movement of the control shall yield a large movement of the display element.
 - 2. When a small range of display movement is required, a large movement of the control shall result in a small movement of the display, consistent with accuracy requirements.
- c. Coarse/Fine Knob Setting - A rotary knob used for coarse control shall move an associated display element (linear scale) 3-6 times the distance of a fine control knob per revolution of the knob.
- d. Bracketing - When bracketing is used to locate a maximum or minimum value (e.g., as in tuning a transmitter), the control knob shall swing through an arc of not less than 10 degrees nor more than 30 degrees either side of the target value in order to make the peak or dip associated with that value clearly noticeable.
- e. Counter - When counters are provided, the control/display ratio shall be such that one revolution of the knob produces approximately 50 counts.

9.2.3.2.10 Control/Display Complexity and Precision Design Requirements

Requirements governing control and display complexity are presented below:

- a. Controls/Displays and System Compatibility - The complexity and precision of the control and display system shall be consistent with the precision required by the overall system.
- b. Information Processing Ability - Displayed information shall not exceed the user's perception or information processing ability (e.g., displays which are too complex or too briefly presented to be understood.) Display information shall consist of only information that is pertinent to the operator's task at hand. Where it is necessary to have a complex display, means shall be explored to simplify it: by providing an option to choose more or less detail, an option to display data in either an alphanumeric or graphic format, or by organizing the information in spatially isolated, highlighted, or "boxed-around" groups.
- c. Motor Ability - The required operation of controls shall not exceed the user's manipulative ability under the dynamic condition and environment in which human performance is expected to occur (e.g., manual dexterity, coordination, force and torque generation, and reaction time shall not be exceeded).

9.2.4 Human/Workstation Configuration

9.2.4.1 Human/Workstation Configuration Design Considerations - N/A

9.2.4.2 Human/Workstation Configuration Design Requirements

9.2.4.2.1 Workstation Anthropometric Design Requirements

Workstations/Display and Control Panels shall be designed to accommodate the SSF crew.

- a. G-level - The physical dimensions and layout of workstations, display and control panels shall conform to user characteristics for the particular G-level under which they are to be used (e.g., neutral body posture vs. 1-G posture).
- b. Movement - Workstations/display and control panels shall be laid out in such a way that operator body motion required for workstation/display and control panels functions shall be minimized to the extent possible. Priority shall be given to the most frequently or time critical functions. Micro-g countermeasure features shall be incorporated into the design to the extent possible.
- c. Musculoskeletal Tension - Workstation/display and control panels design shall minimize the musculoskeletal tension required to maintain position/posture required for workstation/display and control panels operation.
- d. Deconditioned State - Workstation/display and control panels design shall consider special crewmember orientation requirements due to the deconditioned state of the crewmembers as defined in section 4.10.

9.2.4.2.2 Visual Space Design Requirements

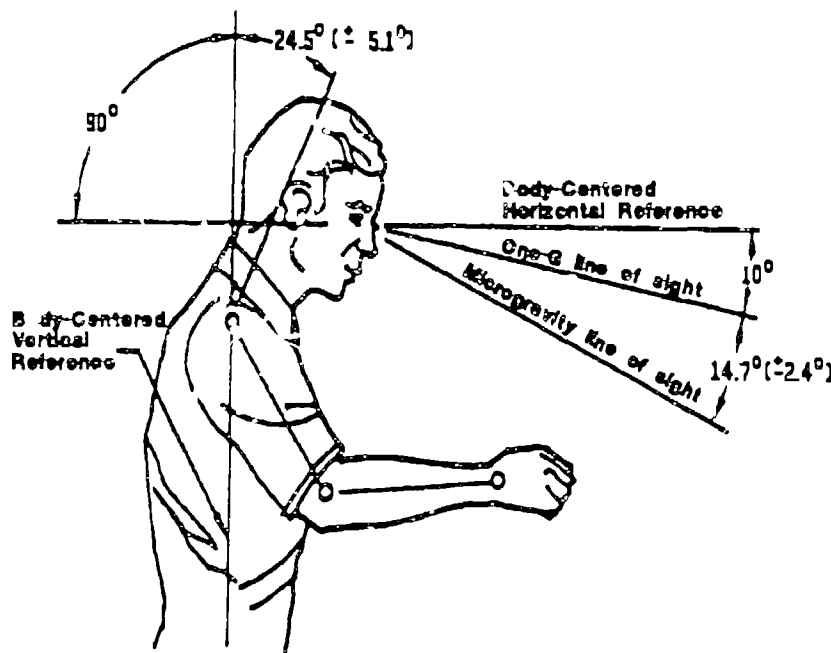
Good workstation/display and control panels design shall accommodate the visual abilities of users. Requirements and specifications regarding a crewmember's visual space are provided below:

a. Viewing Distance:

- 1. Minimum - The effective viewing distance to displays, with the exception of visual display terminal (VDT) displays and collimated displays, shall not be less than 330 mm (13 in.) and preferably not less than 510 mm (20 in.).

When using a VDT, a minimum viewing distance of 410 mm (16 in.) shall be provided. The recommended distance depends on the detail and resolution of the display, but would generally be greater than 410 mm (16 in.). When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 250 mm (10 in.).

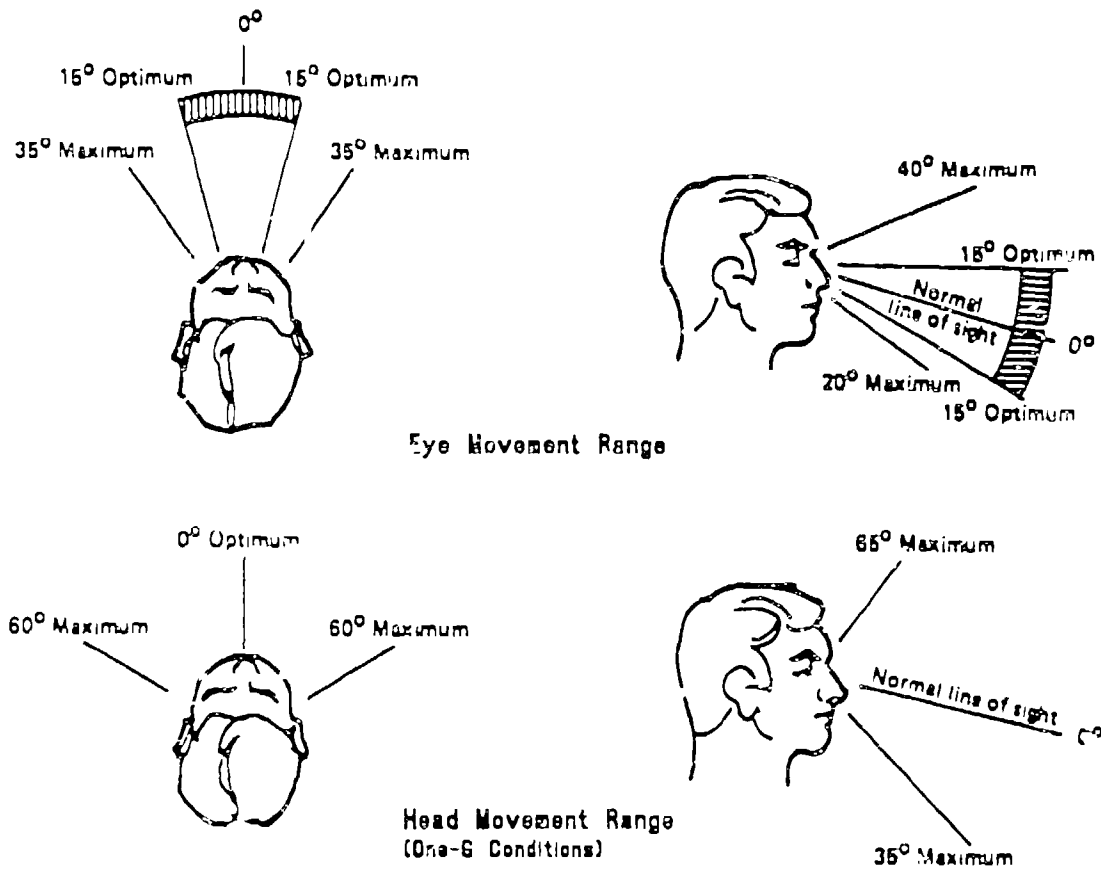
2. **Maximum** - The maximum viewing distance to displays located close to their associated controls is limited by reach distance and shall not exceed 710 mm (28 in.). For other displays, there is no maximum limit, other than that imposed by space limitations and visual requirements, provided the display is properly designed.
- b. **Line of Sight** - A crewmember's line of sight depends on body position and varies as a function of gravity level as shown in Figure 9.2.4.2.2-1.
- c. **Field of View** - The field of view for a particular observer position is determined by eye and head movements.
 1. The eye movement component for microgravity and 1-G is shown in Figure 9.2.4.2.2-2. (Note that the field of view is measured with respect to the vertical references shown in Figure 9.2.4.2.2-1.)
 2. The head movement component for 1-G is shown in Figure 9.2.4.2.2-2. Microgravity head movement data are not yet available and probably differs from 1-G.
 3. Guidelines to accommodate deconditioned crewmembers are found in section 4.10.
- d. **Visual Distractions** - Workstations/display and control panels shall be designed so that stimuli distracting to the operator are minimized.



Reference: 1, page 22-2

Figure 9.2.4.2.2-1 Line-of-Sight for One-G and Microgravity

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Reference: 2, page 27

Figure 9.2.4.2.2-2 Eye and Head Movement Ranges
Line-of-Sight Depends on G-Level)

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9.3 CONTROLS

9.3.1 Introduction - N/A

9.3.2 Controls Design Considerations - N/A

9.3.3 Control Design Requirements

9.3.3.1 General Requirements

General requirements for the design of controls are provided below.

a. Standardization - Controls shall be standardized to the maximum extent practical. Specific aspects to be standardized include, but are not limited to, the following areas:

1. Control operation.
2. Control mounting and guarding.
3. Control orientation.
4. Control size and color.

5. Nonstandardization of control design shall be employed only if meaningful (e.g., red indicates an emergency control).

b. Multi-g Controls - Controls to be used under prolonged or transitory acceleration forces above 2 g's shall be designed to accommodate the crewmember's altered physical abilities.

c. Microgravity Controls - Crew restraints shall be provided for use at all microgravity workstations.

d. Detent Controls - Detent controls shall be selected over continuous controls whenever the operational mode requires control operation in discrete steps.

e. Stops - Stops shall be provided at the beginning and end of the range of control positions if the control is not required to be operated beyond the indicated end positions or specified limits.

f. Load Limit - Controls shall withstand the crew-imposed limit loads given in Figure 9.3.3.1-1 as a minimum.

g. Blind Operation - Where "blind" operation (i.e., actuation without visual observation) is necessary, the controls shall be shape coded or separated from adjacent controls by at least 13 cm (5 in.)

Item	Type of Load	Design Limit load	Direction of load
Levers, handles, operating wheels	Push or pull concentrated on most extreme tip or edge	220 N (49.48 lbf)	Any direction
Small knobs	Torsion	15 Nm (11 ft-lb)	Either direction

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Reference 1, page 4.9-2

**Figure 9.3.3.1-1 Maximum Crew Induced Design
Limit Loads (Controls)**

h. High-Force Controls - In general, controls requiring operator forces exceeding the strength limits of the lowest segment of the expected user population shall not be used. High-force controls shall only be used when the operator's nominal working position and/or restraint system provides proper support.

i. Miniature Controls - Miniature controls (e.g. DII switches) shall not be used in the design of controls used by the crewmember.

9.3.3.2 Accidental Actuation Design Requirements

Requirements for reducing accidental actuation of controls is presented below.

a. Design and Location - Controls shall be designed and located so as to minimize susceptibility to being moved accidentally. Particular attention shall be given to critical controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions.

b. Protective Methods - Adequate protection shall be provided for controls that are susceptible to accidental actuation. Protective methods include, but are not limited to, those listed below.

1. Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.
2. Recess, shield, or otherwise surround the controls by physical barriers. The control shall be entirely contained within the envelope described by the recess or barrier.
3. Cover or guard the controls. Safety or lock wire shall not be used.
4. If a cover guard is used, its location when open shall not interfere with the operation of the protected device or adjacent controls.

5. Provide the controls with interlocks so that extra movement (e.g., lifting switch out of a locked detent position) or the prior operation of a related or locking control is required.

6. Provide the controls with resistance (i.e., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation.

7. Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential actuation is necessary (i.e., the control moved only to the next position, then delayed).

c. Noninterference - Protection devices shall not interfere with the normal operation of controls or the reading of associated displays.

d. High-Traffic Areas - Critical controls shall not be located in high-traffic paths or translation paths. If controls must be placed in these locations, means shall be used to prevent inadvertent actuation (i.e., pull to unlatch toggle switches).

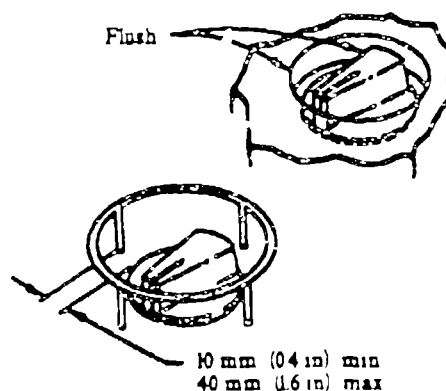
e. Dead-Man Controls - Where appropriate, controls, which result in system shutdown to a noncritical operating state when force is removed, shall be utilized where operator incapacity can produce a critical system condition.

f. Barrier Guards:

1. Barrier guard spacing requirements for use with toggle switches, rotary switches, and thumbwheels is shown in Figure 9.2.3.2.1-1.

2. Accidental actuation of controls can result when crewmembers use barrier guards as handholds. Barrier guards shall be designed and located so as to minimize this problem.

g. Rotary Switch Protection - Rotary switches that control critical experiment or vehicle functions shall be recessed or have barrier guards. Dimensions are shown in Figure 9.3.3.2-1.



Reference: 1, page 4.8-10

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Figure 9.3.3.2-1 Rotary Switch Guard

- h. Detachment - Covers and guards shall be designed to prevent accidental detachment during operational periods.
- i. Position Indication - When protective covers are used, control position shall be evident without requiring cover removal.
- j. Hidden Controls - When hidden controls (i.e., controls that cannot be directly viewed) are required they shall be guarded to prevent inadvertent actuation.
- k. Hand Controllers - Hand controllers shall have a separate on/off control to prevent inadvertent actuation when the controller is not in use.
- l. Circuit Breaker Protection - When circuit breakers are ganged in a common array, a cover shall be used as an additional security measure to prevent inadvertent actuation or damage.

9.3.3.3 Control Types Design Requirements

9.3.3.3.1 Knob Design Requirements

Requirements for the design of knobs are provided below.

a. Discrete Rotary Selection Switches:

1. General:

- a) Rotary selector switches shall be used when four or more detented positions are required for discrete functions.
- b) Rotary selector switches shall not be used for a two-position function unless ready visual identification of control position is of primary importance, and speed of control operation is not critical, or unless the use of other types of switches is not feasible.

2. Displacement - Up to 12 switch positions may be provided. Standard distance between positions shall be 30 degrees.

3. Knob dimensions - Pointer knobs of the type illustrated in Figure 9.3.3.2-1 are preferred for general use. Dimensions and alternate designs are, in order of preference, described within MIL-K-25049 and MIL-H-8810 (most preferred), MIL-STD-1472, AFSC DH 2-2 and MIL-STD-1348.

4. Separation and arrangement:

- a) Rotary selector switches shall be designed with a moving pointer and a fixed scale.
- b) The pointer knob shall be mounted sufficiently close to its scale to minimize parallax error between the pointer and the scale markings. When viewed from the normal operator's position, the parallax error shall not exceed 25% of the distance between scale markings.

c) Switch design and scale placement shall be such that there is no reasonable possibility of confusing the pointer-end and nonpointer-end of a knob.

5. Resistance - Switch resistance shall be elastic, building up, then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions. The torque required to turn the switch from one detent position to another shall be no less than 9 N-cm (12 in. oz) at breakout and no more than 70 N-cm (100 in. oz) just prior to dropping into the next detent position.

6. Direction of movement - The order of positions shall be such that clockwise movement indicates "on" ascending order, increased performance, etc.

b. Continuous Rotary Control Knobs:

1. General:

a) Continuous rotary control knobs (e.g., rheostats, potentiometers) shall be used for precise adjustment of system parameters.

b) Continuous controls may be either single-turn or multiturn.

2. Displacement - Single-turn controls shall have a preferred standard deflection of 240 degrees, between limits located at the 8 o'clock and 4 o'clock positions.

3. Resistance - The torque required to reposition the knob shaft shall be 6 to 25 N-cm (8 to 36 in. oz).

9.3.3.3.2 Thumbwheel Control Design Requirements

Design requirements for thumbwheel controls are provided below.

a. Discrete Position Thumbwheels :

1. Discrete position thumbwheels shall have 10 or fewer detent positions. The standard distance between positions shall be 36° .

2. Maximum deflection shall be 360° or less if 10 or fewer positions are required.

3. Each position around the circumference of a discrete thumbwheel shall have a slightly concave surface or shall be separated by a high-friction (e.g., knurled) area that is raised from the periphery of the thumbwheel.

4. Resistance shall be elastic, building up and then decreasing as each detent is approached so that the control snaps into position without stopping between adjacent detents. The resistance of discrete thumbwheel controls to movement shall be between 11 and 34 N-cm (16 to 48 in. oz).

5. Movement of the thumbwheel forward, up, or to the right shall produce an increase in the setting value.

b. Continuous Types Thumbwheels:

1. Continuous type thumbwheels shall have a standard deflection of 300° .
2. Hard stops shall be provided to limit the maximum travel of continuous thumbwheels.
3. Continuous thumbwheels shall employ high-friction raised areas to facilitate movement.
4. The resistance of continuous thumbwheel controls to movement shall be between 1 and 4 N-cm (2 and 6 in.oz.).
5. Movement of the thumbwheel forward, up, or to the right shall produce an increase in the setting value.

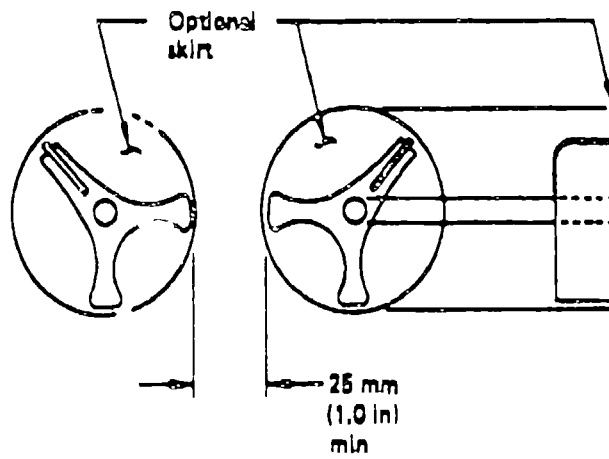
c. Coding:

1. Thumbwheel controls shall be coded by location, labeling, or color (e.g., reversing the colors of the least significant digit wheel as on typical odometers).
2. Where used as input devices, thumbwheel switch OFF or NORMAL positions shall be color coded to permit a visual check that the digits have been reset to these positions (if applicable).

9.3.3.3.3 Valve Control Design Requirements

Requirements for the design of valve controls are provided below.

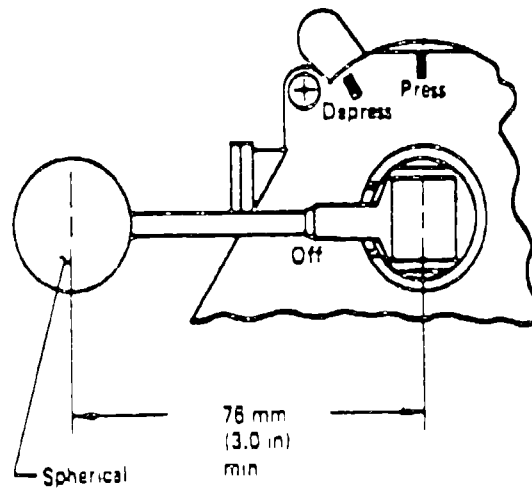
- a. Low-Torque Valves - Valves requiring 1 N-m (10 in-lb) or less for operation are classified as "low-torque" valves and shall be provided with a handle, 5.5 cm (2.25 in.) or less in diameter, (see "d" below).
- b. Intermediate-Torque Valves - Valves requiring between 1 and 2 N-m (10 and 20 in-lb) for operation are classified as "intermediate torque" valves and shall be provided with a "central pivot" type handle 5.5 cm (2.25 in.) or greater in diameter, or a "level" (end pivot) type handle, 7.5 cm (3 in.) or greater in length (the exact size shall be determined by the particular application).
- c. High-Torque Valves - Valves requiring 2 N-m (20 in-lb) or more for operation are classified as "high-torque" valves and shall be provided with handles greater than 7.5 cm (3 in.) in length.
- d. Handle Dimensions:
 1. Valve handles shall approximate the configuration illustrated in Figures 9.3.3.3.3-1 and 9.3.3.3.3-2.
 2. Handles shall be contoured and finished so as to permit ease of operation.
 3. Circular handles, when used, shall have crowns or shall employ concave areas or convex projections along the periphery of the handle.



Reference: 194, page 16

Figure 9.3.3.3.1 Valve Handle - Central Pivot Type

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Reference: 124, page 16

Figure 9.3.3.3.2 Valve Handle - Lever Type

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e. Direction of Operation - Rotary valve controls shall open the valve with a counterclockwise motion.

9.3.3.3.4 Crank Design Requirements

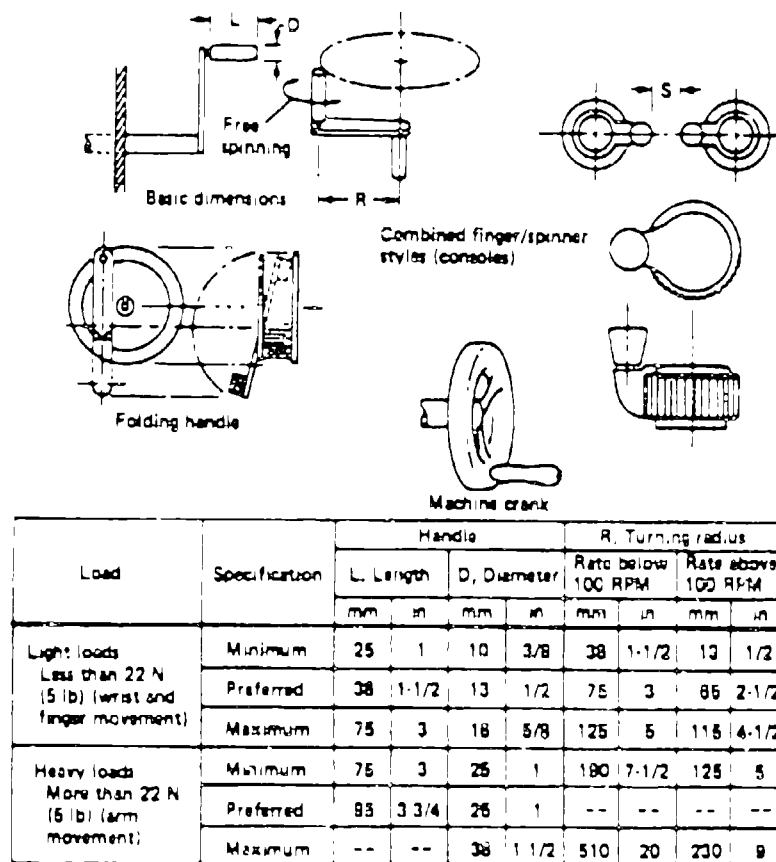
Requirements for the design of cranks are provided below.

a. Dynamics:

1. Where cranks are used for tuning or other processes involving numerical selection, each rotation shall correspond to a multiple of 1, 10, 100, etc.
2. The gear ratio and dynamic characteristics of such cranks shall allow precise placement of the follower (e.g., crosshairs) without overshooting or undershooting and successive corrective movements.

b. Grip Handle - The crank grip handle shall be designed so that it turns freely around its shaft.

c. Dimensions, Resistance, and Separation - Dimensions, resistance, and separation between adjacent swept circular areas of cranks shall conform to the criteria of Figure 9.3.3.3.4-1.



S, Separation between adjacent controls: 75 mm (3 in) minimum
Reference: 2, page 83

Figure 9.3.3.3.4-1 Cranks

d. **Folding Handle** - If a crank handle could become a hazard to persons passing by, or it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle type control shall be used. Such a control shall be designed so that the handle is firmly held in the extended position when in use and folded when not in use.

9.3.3.3.5 Handwheel Design Requirements

Requirements for the design of handwheels are provided below.

- a. **Restraints** - When designed for use in microgravity, adequate restraints shall be provided for the operator.
- b. **Turning Aids** - Knurling, indentation, high-friction covering, or a combination of these shall be built into the handwheel to facilitate operator grasp for applying maximum torque and to reduce the possibility of the wheel being jerked from the operator's hands.
- c. **Spinner Handles** - For applications where the wheel may be rotated rapidly through several revolutions, a spinner handle may be added. Such handles shall not be used, however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety hazard.

9.3.3.3.6 Lever Design Requirements

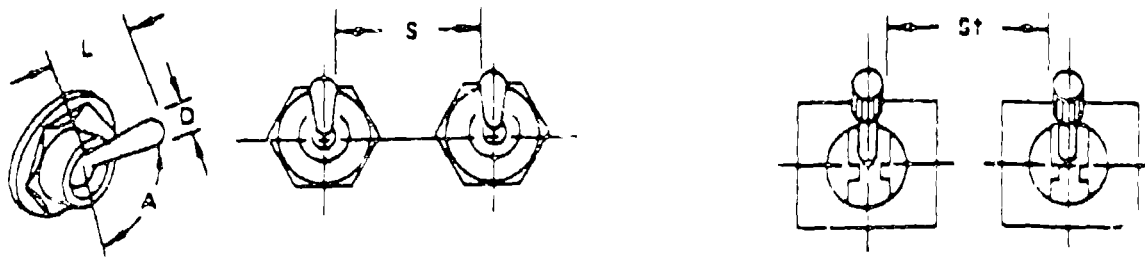
Requirements for the design of levers are provided below.

- a. **Coding** - When several levers are grouped in proximity to each other, the lever handles shall be coded.
- b. **Length** - The length of levers shall be determined by the mechanical advantage needed.

9.3.3.3.7 Toggle Switch Design Requirements

Requirements for the design of toggle switches are provided below.

- a. **Dimensions** - Dimensions for a standard toggle switch shall conform to the values presented in Figure 9.3.3.3.7-1.
- b. **Indication of Actuation:**
 - 1. An indication of control actuation shall be provided (e.g., snap feel, audible click, associated or integral light).
 - 2. Switch design shall preclude stoppage between positions.
 - 3. Visual verification of switch position shall be obtainable at a glance from any viewing angle.



	Dimensions		Resistance	
	L Arm length	D Control tip	Small switch	Large switch
Minimum	13 mm (1/2 in)	3 mm (1/8 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

	Displacement between positions	
	2 position	3 position
Minimum	30°	17°
Maximum	80°	40°
Desired		25°

	Separation			
	Single finger operation		Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (3/4 in)	25 mm (1 in)	13 mm (1/2 in)	16 mm (5/8 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

† Using a lever lock toggle switch

Reference: 2, page 93

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Figure 9.3.3.3.7-1 Toggle Switches

c. Operating Force:

1. Operating force shall be in the range of 3 to 30 N (0.63 to 6.25 lbf).
2. The selected force value shall be dependent upon the specific application (e.g., high-force switches are especially suited for applications where positive-feel is important).
3. For lever-lock (pull-to-unlock) toggle switches, resistance of lift-to-unlock mechanisms shall not exceed 13 N (3 lbf).

d. Orientation - The preferred direction of toggle switch operation shall be vertical. Horizontal actuation of toggle switches shall be employed only for compatibility with the controlled function or equipment location.

e. Position Designation - Switch actuation shall control the system or subsystem functions as indicated in Figure 9.3.3.3.7-2.

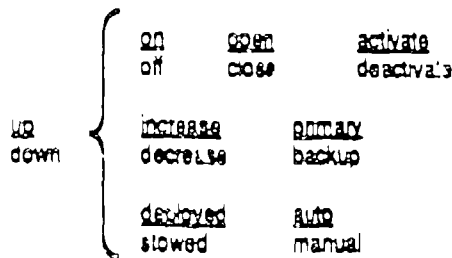
f. Off Position - Where a third position is added for off, the off mode shall be located in the center position, except where this would compromise equipment performance. In this case, off shall be in the bottom position.

9.3.3.3.8 Pushbutton Design Requirements

Requirements for the design of pushbutton controls are provided below.

a. Activation:

1. Latching Pushbutton (push-on, lock-on) - The button displacement. Activation shall be indicated by a sudden drop in resistance and, if possible, an audible click.
2. Momentary Pushbutton (push-on, release-off) - Activation shall be indicated by positive feedback.



Reference: 1, pages 4.9-12

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Figure 9.3.3.3.7-2 Toggle Switch Position Designation

3. Alternate Action Pushbutton (push-on, push-off) - Activation shall be indicated by a sudden drop in resistance, an auditory click, and an associated display action.

4. Touch Sensitive (nonmechanical) - Activation shall be indicated by positive feedback.

b. Resistance - The resistance of pushbuttons to movement shall be 2.78 to 23.63 N (10 to 65 oz). The nominal force-resistance value shall be determined by the particular application and the environment in which it is operated.

c. Dimension:

1. The standard shape of pushbuttons shall be rectangular.

2. Round pushbuttons shall be used when dictated by special functional or hardware considerations.

3. When a pushbutton surface is not concave, the surface shall provide a high degree of frictional resistance to prevent slipping.

4. The height and width (or diameter, as applicable) of pushbuttons shall be 2 cm (0.75 in.) minimum and 4 cm (1.50 in.) maximum.

5. The illuminated area of pushbutton signal lights shall not be less than 3 cm² (0.40 in.²) and not greater than 10 cm² (1.5 in.²).

d. Displacement:

1. Momentary pushbuttons shall have a total displacement of 0.32 to 1.84 cm (0.125 to 0.725 in.).

2. Latching pushbuttons shall have a total displacement of 0.64 to 1.84 cm (0.250 to 0.725 in.).

3. Alternate action pushbuttons shall have a displacement of 0.32 to 1.84 cm (0.125 to 0.725 in.).

4. Pre-travel shall be 0.32 to 1.52 cm (0.125 to 0.6 in.).

5. Over-travel shall be 0.32 cm (0.125 in.) maximum.

9.3.3.3.9 Foot-Operated Switch Design Requirements - N/A

9.3.3.3.10 Pedal Design Requirements - N/A

9.3.3.3.11 Rocker Switch Design Requirements

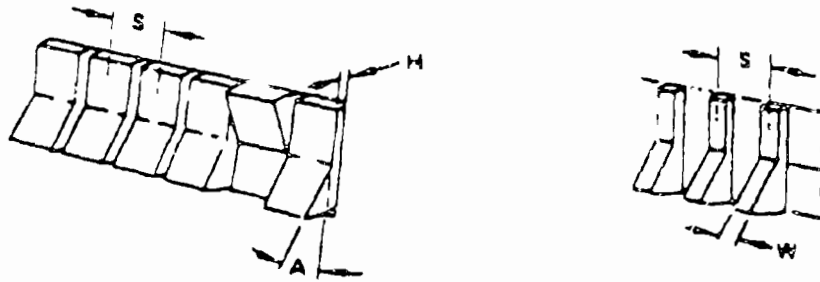
Design requirements for rocker switches are provided below.

a. **Positive Indication** - An indication of control activation shall be provided (e.g., snap feel, audible click, associated or integral light).

b. **Dimensions, Resistance, Displacement, and Separation** - Dimensions, resistance, displacement, and separation between centers of rocker switches shall conform to the criteria in Figure 9.3.3.3.11-1. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

c. **Orientation:**

1. Where practicable, rocker switches shall be vertically oriented.
2. Activation of the upper wing of a rocker switch shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up.
3. Horizontal orientation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.



	Dimensions		Resistance
	W, Width	L, Length	
Minimum	9 mm (1/4 in)	13 mm (1/2 in)	2.8 N (10 oz)
Maximum			11 N (40 oz)

	Displacement		Separation (center-to-center)
	H, Ht. Depressed	A, Angle	s (bare hand)
Minimum	3 mm (1/8 in)	30°	18 mm (3/4 in)

Reference: 2, page 96

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Figure 9.3.3.3.11-1 Rocker Switches

9.3.3.3.12 Push-Pull Control Design Requirements

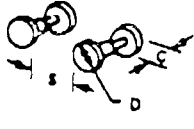
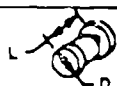

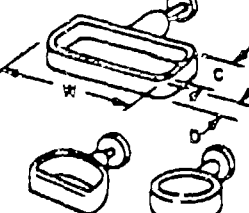
Design requirements for push-pull controls are provided below.

a. Handle Dimensions, Displacement, and Clearances - Handle dimensions, displacement, and clearances for push-pull control handles shall conform to criteria in Figure 9.3.3.3.12-1.

b. Rotation:

1. Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to a nonrotating shaft.

2. When the control system provides a combination push-pull/rotate functional operation using a knob style knob, the rim of the knob shall be serrated to denote (visually and tactually) that the knob can be rotated, and to facilitate a slip-free finger grip.

Configuration example	Application criteria	Design criteria				
		Dimensions			Displacement	Separation
	Push-pull control, low resistance, for two-position mechanical and/or electrical systems. Alternate three position plus rotary function acceptable for application such as vehicle headlight plus parking lights, panel and dome lights provide serrated rim.	D, min dia 19 mm (3/4 in)	C, min clearance 25 mm (1 in) Add 13 mm (1/2 in) for gloved hand		25 ± 13 mm (1 ± 1/2 in) min between push positions 13 mm (1/2 in)	8, min space between 38 mm (1-1/2 in) Add 13 mm (1/2 in) for gloved hand
	Alternate handle, miniature electrical panel switch only. Avoid glove use application.	D, min dia 8 mm (1/4 in)	N/A	L, min length 19 mm (3/4 in)	Minimum 13 mm (1/2 in)	S, min space between 25 mm (1 in)
	High force push-pull, for two-position mechanical system only.	W, min width 100 mm (4 in)	D, depth 16-38 mm (5/8-1-1/2 in)	C, min clearance 38 mm (1-1/2 in) Add 8 mm (1/4 in) for gloved hand	Minimum 25 mm (1 in) Preferred 50 mm (2 in)	S, min space between 13 mm (1/2 in)
	Same as above. Preferred where possible garment or cable snag possibility exists. Note: 1 and 2 finger pulls also acceptable for less than 18 N (4 lb) applications.	W, min width 100 mm (4 in) Add 25 mm (1 in) for gloves	D, depth 16-38 mm (5/8-1-1/2 in)	C, min clearance 32 mm (1-1/2 in)	Minimum 25 mm (1 in) Preferred 50 mm (2 in)	

Reference: 2, page 100

Figure 9.3.3.3.12-1 Push-Pull Controls

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c. Detents - Mechanical detents shall be incorporated into push-pull controls to provide tactile indication of positions.

d. Action of push-pull controls shall be:

1. Pull towards the operator for ON or activation; push away for OFF or deactivation.
2. Clockwise for activation or increasing function of combination pull/rotary switches.

e. Resistance - Force for pulling a panel control with fingers shall be not more than 18 N (4 lb), for pulling a T-bar with four fingers shall be not more than 45 N (10 lb).

9.3.3.3.13 Circuit Breaker Design Requirements

Design requirements for circuit breakers are provided below.

a. General:

1. Circuit breakers shall be used for functions that require automatic protection against excessive electrical currents.
2. Circuit breakers shall be resettable.
3. Except for special cases, circuit breakers shall be of the plunger type (pull-to-release, push-to-reset).
4. All tripped conditions shall be visually indicated.

b. Dimensions - Preferred dimensions for handles of plunger and switch type circuit breakers are illustrated in Figure 9.3.3.3.13-1.

c. Separation and Arrangement - An edge-to-edge distance of 2.5 cm (1.0 in.) nominal, 1 cm (0.5 in.) minimum, shall exist between circuit breakers grouped in horizontal rows, which is the preferred arrangement. The distance between rows shall be a minimum of 2.5 cm (1.0 in.).

d. Displacement:

1. The tripped condition of the plunger-type circuit breaker shall be indicated by a white or silver band. When the circuit breaker is closed the band shall not be visible (see Figure 9.3.3.3.13-1).
2. The "off" or tripped condition of the switch type circuit breaker shall be indicated when the handle is in the "down" position (see Figure 9.3.3.3.13-1).

e. Resistance - The force required to reset a plunger-type circuit breaker shall not exceed 53 N (12 lb). The force required to manually trip a plunger type circuit breaker shall not exceed 35 N (8 lb).

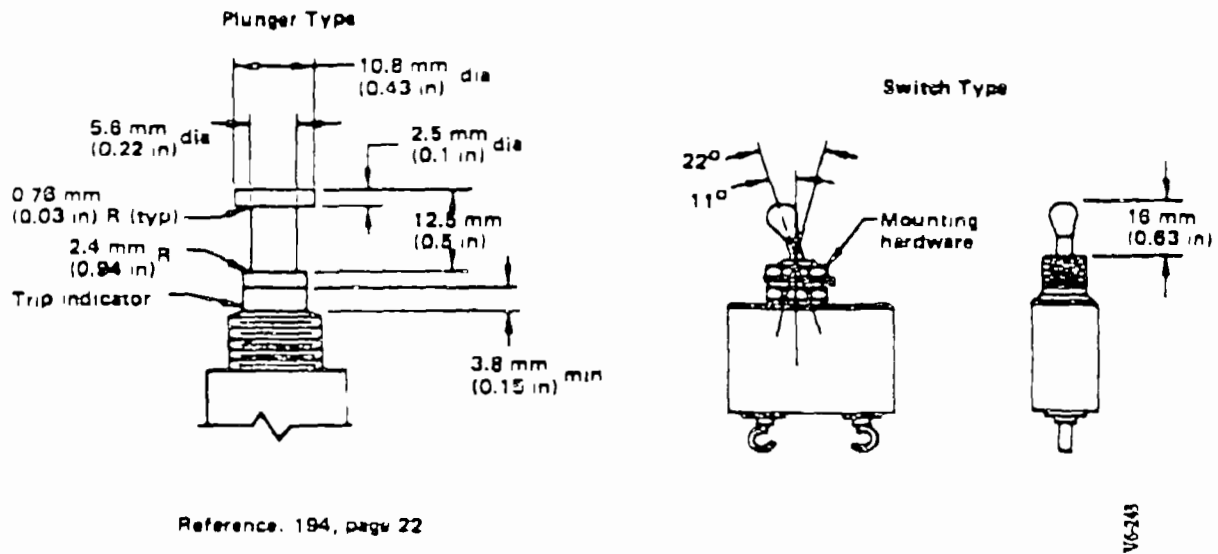


Figure 9.3.3.13-1 Circuit Breakers

9.3.3.3.14 Slide Switch Control Design Requirements

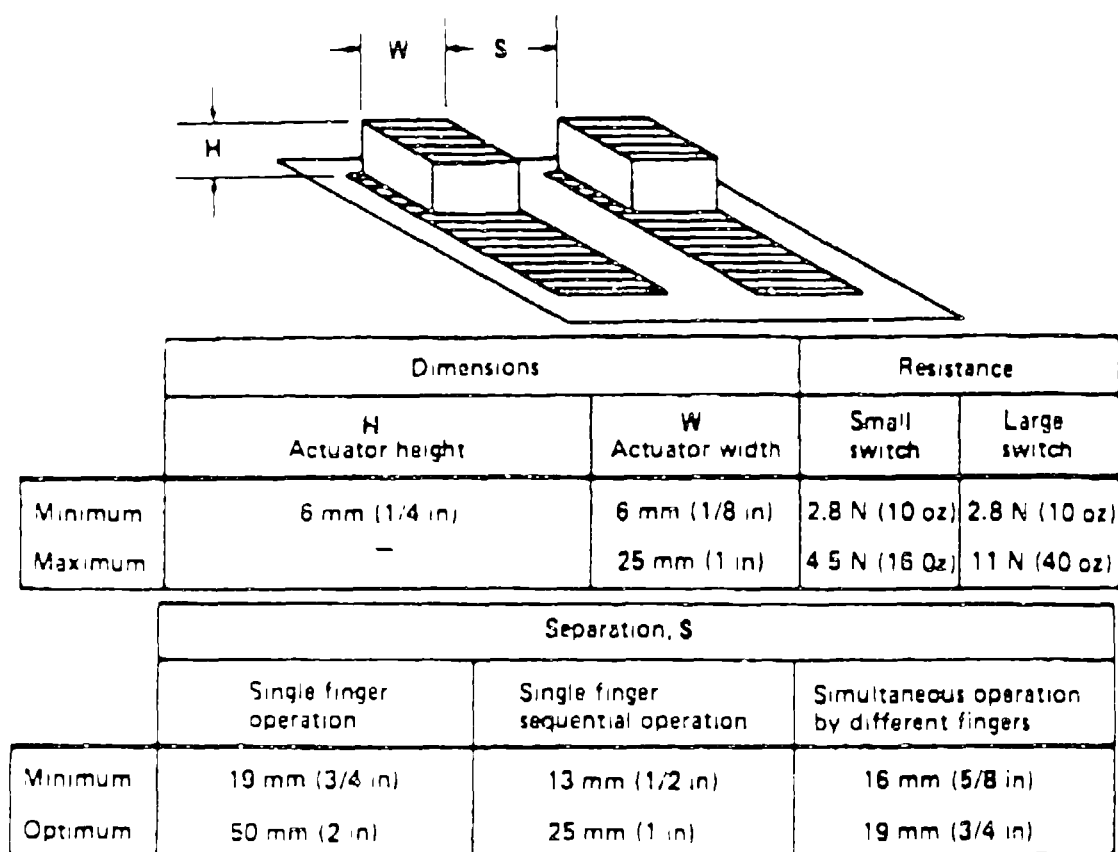
Design requirements for slide switch controls are provided below.

a. Dimensions, Resistance, and Separation:

1. Dimensions, resistance, and separation of slide switch handles shall conform to criteria in Figure 9.3.3.14-1.
2. Detents shall be provided for discrete control settings. Resistance shall gradually increase, then drop when the switch snaps into position.
3. The discrete control slide switch shall not be capable of stopping between positions.

b. Orientation - Where practical, slide switches shall be vertically oriented. Horizontal orientation or actuation of slide switches shall be employed only when necessary for compatibility with a controlled function or equipment location.

c. Positive Indication - Slide-switch controls that are analog or involve more than two discrete positions shall be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle.



Reference 2, page 98

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Figure 9.3.3.3.14-1 Slide Switches

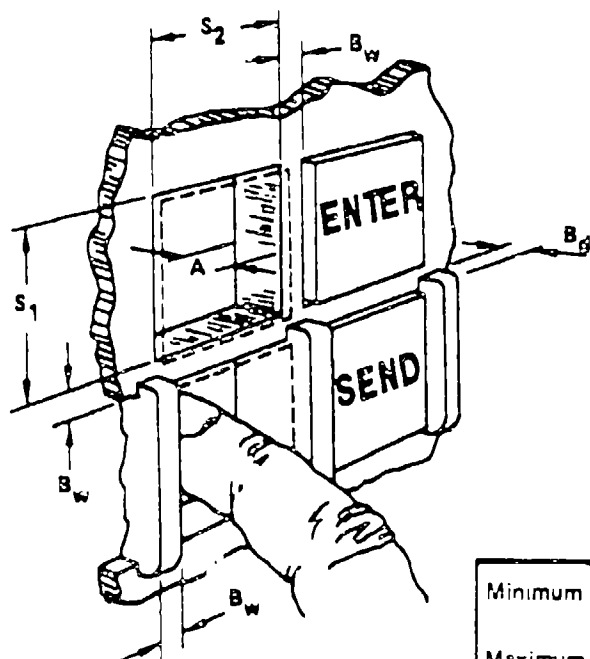
d. Switch Action - Moving the slide up or away from the operator shall result in turning the equipment or component on, causing a quantity to increase, or causing the equipment or component to move forward, clockwise, to the right, or up.

9.3.3.3.15 Legend Switch Design Requirements

Design requirements for legend switches are provided below.

a. Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria in Figure 9.3.3.3.15-1.

b. Barrier Height - Barrier height from panel surface shall conform to the criteria in Figure 9.3.3.3.15-1. Unless otherwise specified, barriers are required on critical switches and on switches likely to be inadvertently actuated. Barriers, when used, shall not obscure visual access to controls, labels or displays.



	S ₁ , S ₂ Size	A Displacement	Barriers		Resistance
			B _w	B _d	
Minimum	19 mm* (3/4 in)	3 mm** (1/8 in)	3 mm (1/8 in)	5 mm (3/16 in)	2.8 N*** (10 oz)
Maximum	38 mm (1-1/2 in)	6 mm (1/4 in)	6 mm (1/4 in)	6 mm (1/4 in)	18.7 N (80 oz)

Notes:

- * 15 mm (5/8 in) where switch is not depressed below the panel
- ** 5 mm (3/16 in) for positive position switches
- *** 5.6 N (20 oz) for use in moving vehicles

Reference: 2, page 94

With Updates

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Figure 9.3.3.3.15-1 Legend Switches

c. Other Requirements:

1. For positive indication of switch activation, the legend switch shall be provided with a detent or click. When touch sensitive switches are used, a positive indication of activation shall be provided, (e.g., an integral light within or above the switch being activated).
2. The legend shall be legible with or without internal illumination.
3. A lamp test or dual lamp/filament reliability shall be provided for switches if the mean time between failure (MTBF) is less than 100,000 hours.
4. Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers. The pushbuttons shall not be susceptible to inadvertent activation during this lamp removal or replacement process.
5. There shall be a maximum of three lines of lettering on the legend plate.

9.3.3.3.16 Printed Circuit (DIP) Switches Design Requirements - N/A**9.3.3.3.17 Key-Operated Switch Design Requirements - N/A****9.3.3.4 Computer Input Devices****9.3.3.4.1 Keyboard Design Requirements**

Requirements for keyboard design are provided below.

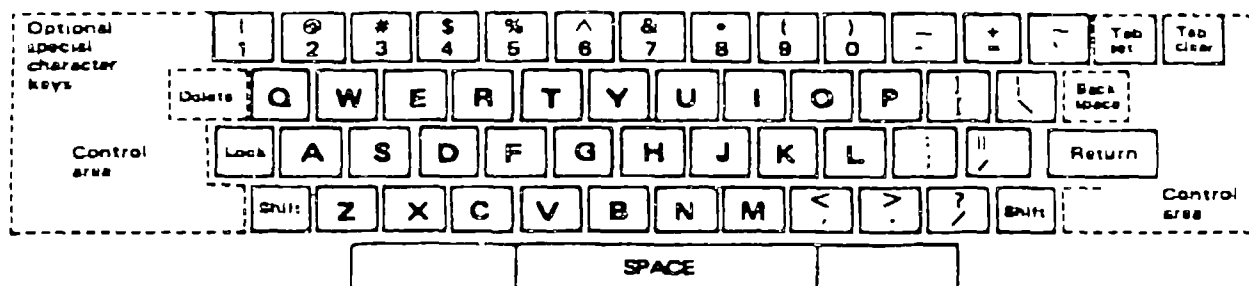
9.3.3.4.1.1 Layout

a. Alphanumerics - The basic alphanumeric character arrangement for standard keyboards shall conform to USA Standard Typewriter Pairing of the American Standard Code for Information Interchange (ASCII). See Figure 9.3.3.4.1.1-1.

b. RESERVED

c. Number keypad - When appropriate, a number keypad shall be added to the keyboard. This shall be to the righthand side of the main keyboard, if workstation layout permits. The arrangement of the numeric keypad shall conform to Figure 9.3.3.4.1.1-2.

d. Function keys - The use of function keys will depend on the specific system that the keyboard is a part of.



Reference 279, page 8-1

Figure 9.3.3.4.1.1-1 Keyboard Layout

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1. Keying Process - Function keys shall be used to make the keying process faster and to minimize keying errors where fast response is required (e.g., contingencies).

2. Location of Function Keys - Certain functions that occur most frequently or that tend to occur together should be placed in the same area.

3. Function Key Types

(a) Fixed Function Keys - Fixed function keys shall be provided for those functions that are widely and frequently used. Examples of commonly used fixed function keys are RESET, BREAK, TRANSMIT, CONTROL, and a means of cursor control.

(b) Cursor Movement Keys - Cursor movement keys shall be arranged in a spatial configuration reflecting the direction of actual cursor movement see Figure 9.3.3.4.1.1-3).

(c) Variable Function Keys - Variable function keys (user programmable) shall be provided whenever it is thought that the system will at present or in the future require the flexibility of these keys.

4. Minimization of Errors - The keyboard layout shall minimize the effect of likely errors, especially those that are critical. For instance, the delete key shall never be located next to the send key or other frequently used keys.

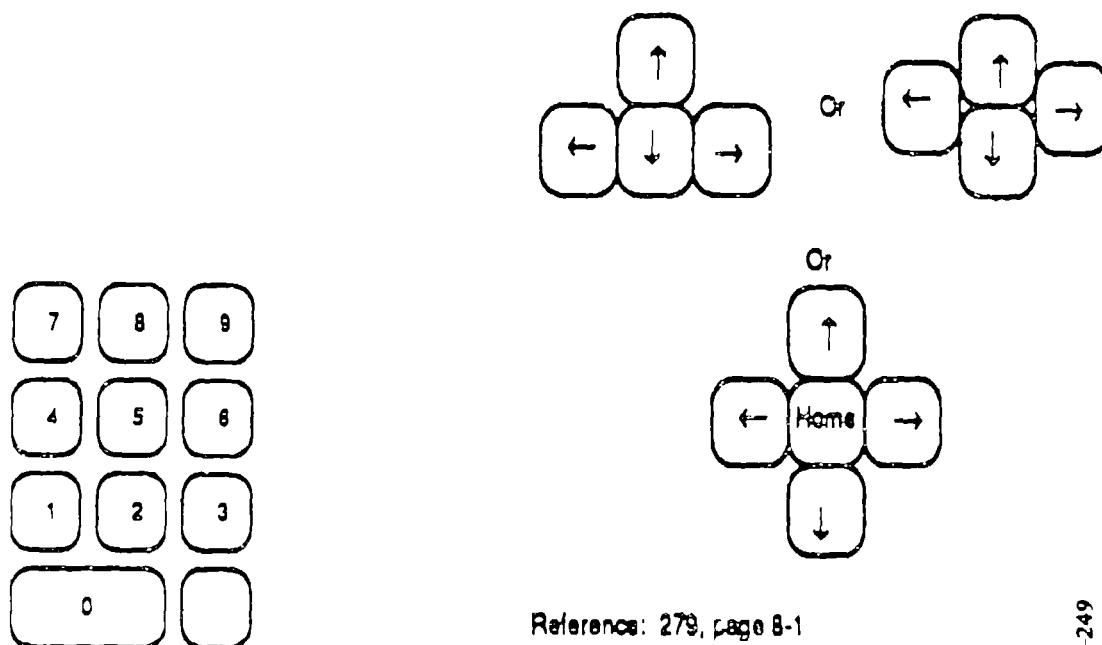


Figure 9.3.3.4.1.1-2 Numeric Keyboard

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Reference: 279, page 8-1

Figure 9.3.3.4.1.1-3 Cursor Movement Keys

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5. Non-ASCII Key Locations - The locations of keys which are not defined by the ASCII USA Standard Typewriter Pairing shall be located using the following guidelines.

- (a) Frequently Used Keys - Frequently used keys shall be placed in the locations in which they are most convenient to use.
- (b) Potentially destructive Keys - Keys with potentially destructive consequences shall be physically protected.
- (c) Grouping - If possible, keys shall be grouped in some logical pattern (e.g., purpose, frequency of use, and type of response) and the user informed of this grouping.

9.3.3.4.1.2 General

- a. Keyboard Design Commonality - There shall be a single design for keyboards, particularly in relation to the location of keys, and it shall be used throughout the ACRV.
- b. Control Switches - All commonly used controls associated with keyboard functioning (e.g., on/off) shall be readily accessible to the user. Both the control and its labeling shall be visible to the user.
- c. Key Markings - The key labels shall be placed on the keys in such a way as to be resistant to wear and abrasion. If the label cannot be placed on the key, it shall be placed above it.
- d. Finger Placement Aids - The "F" and "J" keys on standard keyboards and the "5" on number keyboards shall be distinguishable to the touch to facilitate the correct placement of the fingers for touch typists.
- e. Keyboard Placement - The keyboard placement shall be compatible with the neutral body posture and the restraint system being employed.
- f. Operating Force - The preferred operating force of a terminal keyboard shall be 0.5N (1.75 oz).
- g. Key Displacement - The recommended key displacement for activation is approximately 0.2 cm (0.08 in.) with bottoming out occurring at about 0.4 cm (0.16 in.).
- h. Feedback
 - 1. The screen shall provide visual feedback each time a key is activated.
 - 2. Auditory feedback indicating key activation shall be provided. User shall have the option of deactivating this feedback.
 - 3. Kinesthetic feedback in the form of a distinct "bottoming out" shall be present when keys are maximally depressed.
- i. Keyboard Interlock - Keyboard interlock shall exist to prevent the outputs from two or more simultaneously depressed keys from either jamming the print mechanism or outputting an invalid keycode.

j. Size and Shape of Keys - The shape of keys shall:

1. Aid the accurate location of the user's fingers.
2. Minimize reflections.
3. Provide a suitable surface for the key legends.
4. Be neither sharp nor uncomfortable to press.
5. Have a dished profile curvature for improved keyboarding accuracy.

k. Key Legend - The key legends shall be explicit and easy to understand. Alphanumeric legends shall not be smaller than 0.3 cm (0.12 in.).

l. Color and Reflection of Keys

2. The surface of keys shall have a matte finish to reduce glare.
3. For standard keys, the primary color shall be neutral (e.g., beige or gray) rather than a color that has a high reflectance like white.

m. Function Key Labels - Function keys shall be labeled with standard function symbols, the function title, function title abbreviations, or function codes, in that order of preference.

n. Key Repeat - Alphanumeric and symbol character keys should automatically repeat when held down. The repeat should have a user selectable delay with a default of 0.5 second and a user selectable repeat rate with a default of 0.1 second. The physical release of the key should terminate the repeat.

o. Key Spacing - The spacing of keys shall be as indicated in Figure 9.3.3.4.1.2-1.

p. Noise Level - Both keyboard and terminal shall operate quietly enough so that nearby crewmembers are not bothered by their operation.

9.3.3.4.2 Joysticks Design Requirements

Design Requirements for isotonic and isometric joysticks are provided below.

a. Isotonic Joystick

1. Movement shall be smooth in all directions, and rapid positioning of a follower on a display shall be attainable without noticeable backlash, cross-coupling, or the need for multiple corrective movements.
2. Control ratios, frictions, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning.

	Dimensions	Resistance		
	Key width Bare-handed	Numeric	Alpha-numeric	Dual function
Minimum	10 mm (0.385 in.)	1 N (3.5 oz)	250 mN (0.9 oz)	250 mN (0.9 oz)
Maximum	19 mm (0.75 in.)	4 N (14.0 oz)	1.5 N (5.3 oz)	1.5 N (5.3 oz)
Preferred	13 mm (0.5 in.)			

	Displacement			Separation
	Numeric	Alpha-numeric	Dual function	(between adjacent key tops)
Minimum	0.8 mm (0.03 in.)	1.3 mm (0.05 in.)	0.8 mm (0.03 in.)	6.4 mm (0.25 in.)
Maximum	4.8 mm (0.19 in.)	6.3 mm (0.25 in.)	4.8 mm (0.19 in.)	
Preferred				6.4 mm (0.25 in.)

Reference: 2, Page 91

Note: See Figure 9.2.3.2.1-1 For Non-Keyboard Pushbutton Layout Dimensions

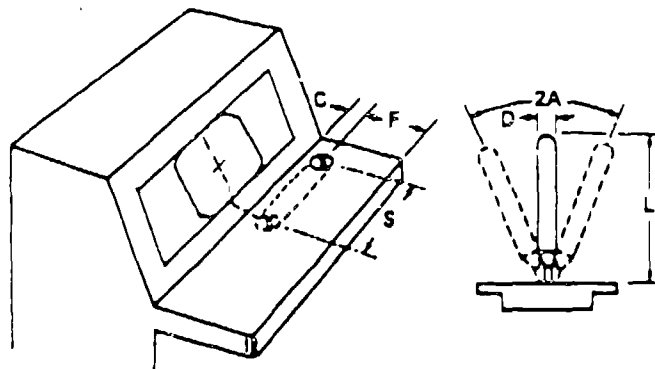
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Figure 9.3.3.4.1.2-1 Keyboard

3. The delay between control movement and the confirming display response shall not exceed 0.1 second.
4. Dimensions, resistance, and clearance shall conform to criteria in Figure 9.3.3.4.2-1.
5. The joystick shall be placed so as not to interfere with other controls.
6. Joystick placement shall allow effective operation when the operator is using the restraint system provided and maintaining an optimum viewing position with respect to the VDT.

b. Isometric Joystick

1. The output shall be proportional to the magnitude of the applied force as perceived by the operator.
2. The isometric joystick shall deflect minimally in response to applied force, but may deflect perceptibly against a stop at full applied force.
3. Isometric joysticks shall be used only when the primary feedback is not kinesthetic, but of some other form (e.g., visual).



	Dimensions		Resistance	Displacement	Clearance		
	Dia, D	Length, L			Display C to stick C, S	Around stick, C	Stick to shelf front, F
Minimum	6.5 mm (0.25 in)	75 mm (3 in)	3.3 N (12 oz)		0		120 mm (4.75 in)
Maximum	16 mm (0.62 in)	150 mm (6 in)	8.9 N (32 oz)	45 deg	400 mm (15.75 in)	*	250 mm (9.88 in)

* Maximum stick excursion plus 100 mm (4 in)

Reference: 279, page 8-5

With Updates

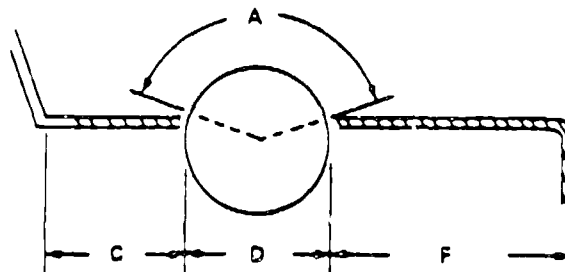
V6-251
Rev A

Figure 9.3.3.4.2-1 Isotonic Joystick

9.3.3.4.3 Light Pen Design Requirements - N/A**9.3.3.4.4 Mouse Design Requirements - N/A****9.3.3.4.5 Track Ball (Rolling Ball) Design Requirements**

Design requirements for a track ball control device are provided below.

- a. Zero-Order Control - A track ball shall be used for zero order control (i.e., a given movement of the ball produces a proportional movement of the follower on the display) or rate control (i.e., cursor movement is proportional to rate of ball movement), selectable by the user.
- b. Follower Recapture - The controller shall not drive the follower off the edge of the display.
- c. Location - Track ball placement shall allow efficient use of the device by crewmembers using workstation restraints and maintaining optimum view of associated VDT.
- d. Dimensions, Resistance, and Clearance - Track ball dimensions, resistance, and clearance shall conform to the criteria in Figure 9.3.3.4.5-1.
- e. Ball Diameter - The smaller diameter ball controls (Figure 9.3.3.4.5-1) shall be used only where space availability is very limited and when there is no need for precision.
- f. Track Ball/Keyboard Integration - The system shall be designed so that the user does not have to alternate frequently between the track ball and the keyboard.



	Dimensions		Resistance		Clearance		
	Diameter, D	Surface exposure, A	Precision required	Vibration or accel conditions	*	Around ball, C	Ball to shelf front, F
Minimum	50 mm (2 in)	100 deg			0	50 mm (2 in)	120 mm (4.75 in)
Maximum	150 mm (6 in)	140 deg	1.0 N (3.6 oz)	1.7 N (6 oz)	320 mm (12.62 in)		250 mm (9.75 in)
Preferred	100 mm (4 in)	120 deg	0.3 N (1.1 oz)				

* Lateral distance from display centerline to ball centerline

Reference 279, page 8-8

Figure 9.3.3.4.5-1 Trackball Design

9.3.3.5 Speech Transmission Equipment Design Requirements

Requirements for the design of speech transmission equipment are provided below.

- a. **Frequency** - Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz.
- b. **Dynamic Range** - The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB.
- c. **Noise-Cancelling Microphones** - In very loud, low-frequency noise environments (100 dB overall), noise-cancelling microphones shall be used and shall be capable of effecting an improvement of not less than 10 dB peak speech to root-mean-square-noise ratio as compared with non-noise-cancelling microphones of equivalent transmission characteristics.
- d. **Pre-emphasis** - If necessary, speech system input devices shall employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 Hz and no greater than 9 dB per octave over the frequency range 1,500 to 4,800 Hz when no clipping is used.
- e. **Peak-Clipping of Speech Signals** - Where speech signals are to be transmitted over channels showing less than 15 dB peak speech to root-mean-square-noise ratios, peak-clipping of 12 to 20 dB may be employed at system input and may be preceded by frequency pre-emphasis as specified in "d" above.
- f. **Noise Shields** - When the talker is in an intense noise field, the microphone shall be put in a noise shield. Noise shields shall be designed to meet the following requirements.
 1. A volume of at least 250 cm^3 (15.25 in^3) to permit a pressure gradient microphone to function normally.
 2. A good seal against the face with the pressure of the hand or the tension of straps.
 3. A hole or combination of holes covering a total area of 65 mm^2 (0.1 in^2) in the shield to prevent pressure buildup.
 4. Prevention of a standing wave pattern by shape, or by use of sound-absorbing material.
 5. No impediment to voice effort, mouth or jaw movement, or breathing.
- g. **Speaker/Side Tone** - The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset.

9.3.3.6 Operating Controls for Voice Communication Equipment Design Requirements

Requirements for the design of operating controls for voice communication equipment are provided below.

a. Volume Controls:

1. Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 110 dB overall when using two earphones.
2. The sound pressure level (SPL) shall be maintained within ± 3 dB when atmospheric pressure changes are encountered within the ACRV.
3. The minimum setting of the volume control shall be limited to an audible level, i.e., it shall not be possible to inadvertently disable the system with the volume control.
4. Separation of power (on-off) and volume control adjustment functions into separate controls is preferred. However, should conditions justify their combination, a noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment. When combined power and volume controls are used, the OFF position shall be labeled.

b. Squelch control - Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated, on-off switch, to deactivate the squelch when receiving weak signals, shall be provided.

9.4 DISPLAYS

9.4.1 Introduction - N/A

9.4.2 Visual Displays

9.4.2.1 Introduction - N/A

9.4.2.2 Visual Display Design Considerations - N/A

9.4.2.3 Visual Display Design Requirements

9.4.2.3.1 Display Readability Design Requirements

9.4.2.3.1.1 Illumination Design Requirements

Workstation lighting requirements are provided below.

a. Luminance Control:

1. When a display will be used under varied ambient illumination, a dimming control shall be provided. The range of the control shall permit the displays to be legible under all expected ambient illumination levels.
2. Dimming to full OFF shall require a positive indication.

b. Dark Adaptation :

1. Partial Dark Adaptation - When the degree of dark adaptation required is not maximum, low brightness white light (preferably integral), that is adjustable as appropriate, shall be used.
2. Complete Dark Adaptation - When complete dark adaptation is required, low luminance ($0.07 - 0.3 \text{ cd/m}^2$) red light (greater than 620 nm) shall be provided for better visibility.

c. Light Distribution:

1. Where multiple displays are grouped together, lighting shall be balanced across the instrument panel such that the mean indicator luminances of any two instruments shall not differ by more than 33% across the range of full ON to full OFF.
2. Light distribution shall be sufficiently uniform within an integrally illuminated instrument such that the ratio of standard deviation of indicator element luminances to mean indicator luminance shall not be more than 0.25, using eight or more equally spaced test measurements.

d. False Indication or Obscuration - Provision shall be made to prevent direct or reflected light from making indicators appear illuminated when they are not, or to appear extinguished when they are illuminated.

9.4.2.3.1.2 Display Contrast Design Requirements

Requirements for contrast within an indicator are provided below.

- a. Indicator Contrast - The luminance contrast within the indicator shall be at least 50%. However, this 50% contrast requirement does not apply to special displays specifically designed for legibility in sunlight.
- b. Low Ambient Illumination - For low ambient illumination applications, contrast shall be at least 90%, with the background luminance less than the figure luminance.

9.4.2.3.1.3 Reflections Design Requirements

Design requirements pertaining to reflections are provided below.

- a. Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of ambient illumination from the display cover.
- b. Reflections in viewing surfaces (e.g., view ports, windshields, etc.) shall be avoided.
- c. Anti-reflection techniques (such as shields and filters) shall not be used if they noticeably degrade display quality.

9.4.2.3.1.4 Vibration Design Requirements

Display design shall be such that vibration of the display and/or the observer shall not degrade display readability below the level required for mission accomplishment.

9.4.2.3.1.5 Display Size Design Requirements

As a minimum, displays shall be of sufficient size to provide readily usable data to the user. This requirement shall hold for all reasonably anticipated locations of the user's relative to the display.

9.4.2.3.2 Information Presentation Design Requirements

Requirements for the presentation of information in visual displays are given below.

- a. Content - The information displayed to an operator shall be prioritized such that the information which is necessary to perform specific actions or to make decisions is easiest to acquire.
- b. Equipment Response - Signal devices, including pushbutton signal lights, shall display equipment response and not merely control position.
- c. Signal Absence:
 - 1. The absence or extinguishment of a signal or visual indication shall not be used to indicate a "ready" or "in tolerance" condition, unless the status of the caution light filament and its associated circuitry can be easily tested by the operator and operator perception of such events is not time critical. Display devices shall have a positive indication of on or ready.
 - 2. The absence or extinguishment of a signal or visual indicator shall not be used to denote a condition; however, the absence of a signal or visual indication shall be acceptable to indicate a "power off" condition for operational displays only - not for maintenance displays.
- d. Range and Accuracy - Display range and readout accuracy shall be consistent with the needs of the crewmembers to manage the spacecraft or equipment, but shall not exceed the accuracy of the input signal.

e. Duration - Non-dynamic signals and display information shall remain displayed until a direct user input cancels them. Dynamic signals and display information shall have durations of sufficient length to be reliably recognized under the highest expected operator workload and all anticipated operational environments.

f. Timeliness Displays (such as CRTs, head-up displays, etc.) requiring refreshed information shall be updated in a synchronous manner, where possible, and be refreshed to the degree of timeliness required by personnel in the normal operating or servicing mode.

g. Display Failure Clarity:

1. Displays shall be designed so that failure of the display or display circuitry shall be immediately apparent to the crew.

2. Where "automatic switch-over" to redundant power or signal sources (due to failure) is implemented, the automatic switch-over shall be made immediately obvious to the crew.

9.4.2.3.3 Display Types

- a. System/equipment status - shall be inferred by the illumination of the indicator, not by the absence of illumination.

- b. Indicator Labeling - shall be provided, close to the indicator, imparting the message intended by the light's illumination.

- c. Indicator Color - The color of the light shall be clearly identifiable and meets with established color standards.

9.4.2.3.3.1 Maintenance Display Design Requirements

Maintenance displays shall be located so they do not interfere with normal flight displays. When possible, they shall not be visible when not in use.

9.4.2.3.3.2 Large Screen Display Design Requirements - N/A

9.4.2.3.3.3 Legend Light Design Requirements

Requirements for legend lights are provided below.

- a. Use - Legend lights shall be used in preference to simple indicator lights except where design constraints demand that simple indicators be used.

- b. ON/OFF Legibility - When not energized, legends shall be legible but shall not appear to be energized (e.g. due to direct sunlight).

- c. Information Presentation - A maximum of three lines of information shall be presented on the display face of a legend light.

d. Light/Switch Determination - It shall be easy to distinguish between legend lights and legend switches throughout the ACRV.

e. Status Indication - System/equipment status shall be inferred by the illumination of the indicator, not by the absence of illumination.

2.3.3.4 Scales and Pointers Design Requirements

Requirements for the design of scales and pointers are provided below.

a. Moving Pointer Circular Scales - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the setting.

b. Moving Pointer Linear Scales - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement up or to the right of the pointer of vertical and horizontal scales and an increase in the magnitude of the reading.

c. Fixed Pointer Moving Scale - Displays with moving scales and fixed pointers or cursors shall be avoided. When circular fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.

d. Fixed Pointer Linear Scale - When use of vertical or horizontal fixed pointer, moving-scale indicators is necessary, clockwise movement of an associated rotary control or movement of a linear control forward, up, or to the right shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.

e. Pointers:

1. Length - The control or display pointer shall extend to, but not overlap, the longest scale graduation marks.

2. Tip configuration - The pointer tip shall be tapered at a 20° angle (40° included angle), terminating in a flat tip equal in width to the minor scale graduations.

3. Mounting - The pointer shall be mounted as close as possible to the face of the dial to minimize parallax (see Figure 9.4.2.3.3.4-1).

4. Color - Pointer color from the tip to the center of the dial shall be the same as the color of the marks. The tail of the pointer shall be the same color as the dial face unless the tail is used as an indicator itself or unless the pointer is used for horizontal alignment.

f. Pattern/Color Coding - When certain operating conditions always fall within a given range on the scale, these areas shall be made readily identifiable by means of pattern or color coding applied to the face of the instrument.

g. Orientation - Alphanumerics on stationary scales shall be oriented in the local vertical position.

h. Zero Position and Direction of Movement - When positive and negative values are displayed around a zero or a null position, the zero or null point shall be located at either the 12 or 9 o'clock position. The magnitude of positive values shall increase with clockwise movement of the pointer, and the magnitude of negative values shall increase with counterclockwise movement. When pointer movement is more than 360° , the zero or reference point shall be located at the 12 o'clock position.

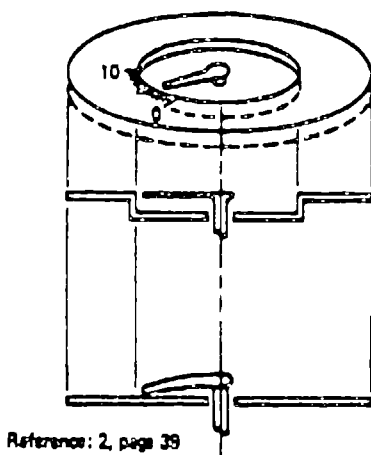
i. Scale Break - There shall be an obvious break of at least 10 degrees of arc between the two ends of the scale, except on multi-revolution instruments such as clocks.

j. Number of Pointers - Whenever precise readings are required, not more than two coaxial pointers shall be mounted on one indicator face.

k. Pointer Alignment - When a stable value exists for given operating conditions in a group of circular-scale indicators, the indicators shall be arranged either in rows so that all pointers line up horizontally on the 9 o'clock position under normal operating conditions or in columns so that all pointers line up vertically in the 12 o'clock position under normal operating conditions. If a matrix of indicators is needed, preference shall be given to the 9 o'clock position.

l. Relative Position of Scale Marks and Number - When reading time and accuracy are critical, circular scale markings and the location of associated numbers shall be arranged to prevent pointers from covering any portion of the scale marks or numerals. The pointer shall come to within 0.8-1.6 mm (0.03-0.06 in.) of all scale markings (See Figure 9.4.2.3.3.4-2).

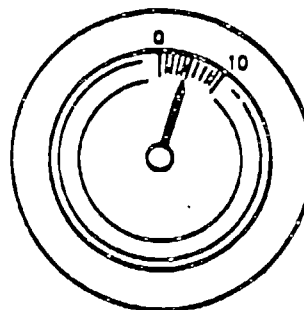
m. Placement of Pointers - Pointers shall be located to the right of vertical scales and at the bottom of horizontal scales.



Reference: 2, page 39

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Figure 9.4.2.3.3.4-1 Scale and Dial Positioning to Minimize Parallax



Reference: 2, page 39

V6-110

Figure 9.4.2.3.3.4-2 Relationship Between Pointer and Scale Marks to Maximize Reading Accuracy

n. **Placement of Numerals** - Numerals shall be placed on the side of the graduation marks away from the pointer to avoid having numbers covered by the pointer. If space is limited (for curved or arc scales) numerals may be placed inside of graduation marks to avoid undue constriction of the scale.

o. **Setting** - If the display will be used for setting a value (e.g., tuning in a desired frequency), the unused portion of the dial face shall be covered, and the open window shall be large enough to permit at least one numbered graduation to appear at each side of any setting.

9.4.2.3.3.5 Clock and Timer Design Requirements

Requirements for the design of clocks and timers are provided below.

a. **Digital Clocks and Timers** - Time measurement indicators shall be of the digital readout type. Where applications require the display of qualitative information (e.g., relative approximate time) other types of indicators (e.g., analog clocks and/or clocks of lesser accuracies) may be used, subject to the approval of the procuring activity.

b. **Format** - Time measurement indicators shall indicate time or time intervals in seconds (00 to 59), minutes (00 to 59), and hours (00 to 23). Values extending beyond 24 hours shall be displayed in terms of days unless otherwise specified. Greater or lesser resolution will be provided as required.

c. **Accuracy** - Accuracy shall meet the requirements of the task.

d. **Control Modes** - Unless otherwise specified, the manual control modes listed below shall be provided for each time measurement indicator.

1. **Start** - Upon activation of the start control line, the indicator shall begin to count within 100 milliseconds.

2. **Stop** - Upon activation of the stop control line, the indicator shall stop within 100 milliseconds.

3. **Reset** - Upon activation of the reset control line, the indicator shall reset to zero within 500 milliseconds.

4. **Slew/Set:**

- a) Individual digit slew control shall be provided.

- b) A manually set indicator shall slew in an upward direction (from the lowest reading to the highest reading) at the rate of 2 digits per second. A downward slewing mode is not required.

- c) For applications where a "direct set" mode is provided in lieu of a timer shall display the commanded reading within 500 milliseconds after the activation of the "enter" or "proceed" command.

d) Upon activation of the count up command and start command, the indicator will count up and continue counting up through zero upon reaching maximum count (e.g., 59:58, 59:59, 00:00, 00:01, 00:02).

e) Upon activation of the countdown command and start command, timers shall countdown to zero and upon reaching zero shall begin to count up (e.g., 00:02, 00:01, 00:00, 00:01, 00:02). This control mode shall be implemented for event timers. The mode shall not be provided for clocks unless specifically requested.

f) There shall be no possibility of ambiguity as to whether a timer is counting toward its target time, or has passed the target time and is counting away from it, if this ambiguity could negatively affect system performance. For example, an overtime light can be used.

9.4.2.3.3.6 Flag Display Design Requirements

Requirements for the design of flag displays are provided below.

- a. Use - Flags shall be used to display qualitative, non-emergency conditions.
- b. Location and Mounting - Flag indicators shall be located above the associated control switch, within meter windows, or with associated items as applicable. Panel flags shall be mounted as close to the surface of the panel as possible without obscuring necessary information.
- c. Snap Action - Flags shall operate by snap action.
- d. Contrast - A minimum of 75% luminance contrast shall be provided between flags and their backgrounds under all expected lighting conditions.
- e. Malfunction Indication - When flags are used to indicate the malfunction of a visual display, the malfunction position of the flag shall obscure part of the operator's view of the malfunctioning display and shall be readily apparent to the operator under all expected levels of illumination.
- f. Positions - Flag indicators shall be restricted to three positions, with preference being given to the two-position type.
- g. Information Content - Each flag indicator shall indicate a single, immediately identifiable event (e.g., the completed opening of a valve).
- h. Legend - Alphanumeric legends shall be used in lieu of, or in addition to, color coding whenever possible. When a legend is provided on the flag, the lettering shall appear upright when the flag assumes the active or no-go position.
- i. Gray Flag - A gray colored (blank position) mechanical "talk back" flag shall mean that a particular system element is in an operational mode or is not inhibited from operation.
- j. Barber Pole Flags - A barber pole (striped) flag shall mean that a particular system element is indeterminate, inactive, or inhibited from operation.
- k. Red Flag - A red flag shall mean that a particular system element has failed.

- l. Test Provision - A convenient means shall be provided for testing the operation of flags.

9.4.2.3.3.7 Digital Display Design Requirements

Requirements for the design of digital displays are provided below.

- a. Mounting - Counters shall be mounted as close as possible to the panel surface so as to minimize parallax and shadows and maximize the viewing angle.
- b. Spacing Between Numerals - The horizontal separation between numerals shall be between one quarter and one half the numeral width. Numbers having more than five digits shall have groups of three digits separated by either blank space equivalent to one-half the width of one character or by commas. Grouping shall start from the right.
- c. Movement:
 1. Snap action - Numbers shall change by snap action in preference to continuous movement.
 2. Update rate - The update rate shall not be faster than two per second.
 3. Reset - The rotation of a counter reset knob shall be clockwise to increase the counter indication or to reset the counter.
 4. Slew rate - Manual slewing modes, when provided, shall be capable of slewing individual digits at a normal rate of two characters per second. A separate control shall be provided for each individual digit (e.g., "units" digit, "tens" digit, etc.), unless otherwise specified.
- d. Illumination - Digital displays shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 3.5 cd/m^2 (1 ft-L).
- e. Individual characters shall normally be limited to the numbers 0 through 9, the capital letters of the English alphabet (A through Z), the plus (+) and minus (-) signs, and the decimal point.
- f. Accuracy - Digital indicators shall possess an internal accuracy equal to or better than the least significant digit displayed by the indicator.
- g. Analog Inputs - When analog-to-digital conversion is required to display an analog signal in digital form, the displayed digit(s) shall reflect the analog signal rounded off to the nearest whole number of the least significant digit displayed (Note: 0.5 shall be rounded up).

9.4.2.3.3.8 Light Emitting Diode (LED) Design Requirements

Requirements for the design of light emitting diodes are presented below.

- a. Intensity Control - LEDs shall be capable of being dimmed.
- b. Color Coding - Use of LED color coding shall conform to Paragraph 9.5.3.2 i, herein.

- c. Lamp Testing - LED indicator lights with less than 100,000 hours mean time between failure (MTBF) shall require a lamp testing capability.

9.4.2.3.3.9 Visual Display Terminal (VDT) Design Requirements

Requirements for the design of visual display terminal (VDT) displays are presented below.

- a. Resolution - All displays shall have a minimum resolution of 67 lines per inch
- b. Luminance - The minimum level of luminance recommended for characters on a VDT, regardless of wavelength, shall be 70 cd/m^2 (20 fL) with a level of 170 cd/m^2 (50 fL) preferred.
- c. Contrast:
 1. Controls - VDTs shall be equipped with controls that permit the crew to optimize VDT discriminability under all anticipated environmental and systems operating conditions. Adjustment of brightness, contrast, and other electronic parameters shall permit the detection of the weakest target that is simulated.
 2. Tolerance - Operating tolerance for contrast shall be 2 %.
 3. Manual control - Under normal operating conditions, a manual VDT brightness control shall be provided allowing selection of contrast between the lowest intensity symbology and its background of from 1:1 to at least 16:1.
 4. High ambient - As the highest ambient light level is reached, the contrast ratio between the lowest intensity symbology and the background shall degrade to not less than 2:1 (unless a lower contrast has been manually selected).
 5. Automatic control - Where critical images (those necessary for crew safety and mission success) are exposed to rapid or frequent changes in ambient light levels, the contrast ratio shall be automatically maintained at a level selected by the operator.
 6. Recommended contrast - The maximum contrast shall be 90%, the minimum shall be 88%. This narrow range applies specifically to alphanumeric displays with contrast defined as given below.

$$\%C = \frac{[(L_c + L_r) - (L_d + L_r)]}{(L_c + L_d + 2L_r)} \times 100$$

C = contrasts

L_c = character luminance

L_d = background luminance

L_r = reflected luminance

d. Glare - Glare from a VDT screen shall be controlled for viewing from any angle within 30° of the axis normal to the screen.

e. Surround:

1. The luminance range of surfaces immediately adjacent to the display shall be between 10% and 100% of screen background luminance.

2. Surfaces adjacent to the display shall have a dull matte finish.

f. Flicker - the refresh rate for VDTs shall not be less than 55 Hz. For alphanumerics presented in negative contrast (dark characters on light background) the refresh rate shall be at least 100 Hz.

g. Viewing Distance and Angle:

1. A nominal viewing distance of 510 mm (20 in.) for VDT use shall be provided.

2. Viewing Angle - All areas of the display surface shall be legible from within at least 30 degrees of the axis centered on, and normal to, the screen.

h. Installation - The face of VDT displays shall be flush with the surface of the panel in which it is installed.

i. VDT Alphanumerics:

1. Character definition - The smallest definition for a dot matrix shall be 5 by 7 dots, with 7 by 9 preferred. If system requirements call for symbol rotation, a minimum of 8 by 11 is required, with 15 by 21 preferred.

2. Character font:

- a) Unless precluded by other requirements, a standard font shall be used across an entire system.

- b) The font shall include lower case characters and allow for descenders.

- c) Superscripts and subscripts shall be provided.

3. Character size:

- a) Character height:

- 1) For extended text, character height shall subtend a minimum of 15 minutes of arc for low definition characters (5x7). The maximum height shall be 22 minutes of arc unless a task analysis indicates need for a greater height in any specific application.

2) Flight display characters (not extended text) shall not subtend less than 24 minutes of visual angle to ensure adequate legibility under launch/entry conditions.

b) Character width - Character width shall be approximately 75% of character height.

c) Stroke width - Stroke width shall be 1/6 to 1/8 of character height.

4. Alphanumeric spacing:

a) Vertical spacing (line spacing) - Vertical spacing between lines shall be great enough so that immediately adjacent ascenders and descenders are separated by at least one blank pixel.

b) Horizontal spacing:

1) Between words - In printed text, normal spacing between words on a line shall be one character width.

2) Between characters - Minimum spacing between successive characters on a line shall be one pixel or 20% of character width (whichever is greater).

c) Descender Length - Descenders shall descend below the line by a distance of 10% to 15% of the upper case letter size.

5. Case - Extended text shall be in uppercase and lowercase letters. Words consisting of uppercase letters shall be used only to attract the operator's attention (e.g., for a label or title).

j. Target Size - When rapid identification is required (e.g., a target of complex shape is to be distinguished from a non-target shape that is also complex), the target signal shall subtend no less than 20 minutes of visual angle at the intended viewing distance. (The term "target" is used to mean any object, symbol, pattern, or marking that an operator must see.)

k. Display Face Facsimiles - Images of scale indicators, digital indicators, signal devices, and other display faces synthesized on VDT screens shall conform to the general requirements previously listed for specific types of displays.

l. Color - When color VDTs are used, they shall possess the capability to display at least four colors (in addition to black and white) for alphanumeric and two-dimensional displays. For three-dimensional graphics displays the VDT shall possess the capability to display at least nine colors.

m. Display Overlays - The VDT shall provide the capability to display video with text and graphic overlays.

n. Highlighting - VDT, as a minimum, shall provide the following highlighting techniques: bold (high intensity) characters, reverse polarity highlighting.

o. Windowing - When windowing capability is used. The user shall have the capability to create windows, delete windows, overlay windows, activate windows, move windows, and size windows. Images within windows shall be scrollable, if they are larger than the window itself.

9.4.2.3.4 Display Maintenance Design Requirements

a. Lamp Redundancy - Incandescent display lighting shall incorporate filament redundancy or dual lamps. When one filament or bulb fails, the intensity of the light shall decrease sufficiently to indicate the need for lamp replacement, but not so much as to degrade operator performance.

b. Lamp Testing - When indicator lights using incandescent bulbs are installed on a control panel, it shall be possible to test all control panel lights at one time. When applicable, design shall allow testing of all control panels at one time. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing.

c. Lamp Replacement - Where possible, lamps shall be removable and replaceable from the front of the display panel. The procedure for lamp removal and replacement shall not require the use of tools and shall be easily and rapidly accomplished.

d. Lamp Removal Safety - Display circuit design shall permit lamp removal and replacement while power is applied without causing failure of indicator circuit components or imposing personnel safety hazards.

9.4.3 Audio Displays

9.4.3.1 Introduction - N/A

9.4.3.2 Audio Displays Design Considerations - N/A

9.4.3.3 Audio Displays Design Requirements

9.4.3.3.1 General Design Requirements

General requirements for the design of audio displays are provided below.

a. False Alarms - The design of audio display devices and circuits shall preclude false alarms.

b. Failure - The audio display devices and circuits shall be designed to preclude warning signal failure related to system or equipment failure and vice versa. Positive and attention demanding indication shall be provided if failure occurs.

c. Circuit Test - All audio displays shall be equipped with circuit test devices or other means of operability testing.

d. Disable - An interlocked, manual disable shall be provided if there is any failure mode which can result in a sustained activation of an audio display.

9.4.3.3.2 Audio Input/Output Equipment Design Requirements

a. Frequency Response - Microphones/input devices, loudspeakers/output devices, and associated audio system devices shall be designed to respond optimally to that part of the speech/audio spectrum most essential to intelligibility (i.e. 200 to 6,100 Hz). Where system engineering necessitates speech transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz. Amplitude variation across the frequency response bandwidth (flatness) shall be not vary more than ± 3 dB.

b. Input devices:

1. Dynamic Range - The dynamic range of a microphone/input devices shall be great enough to admit variations in signal input of at least 50 dB.
2. Noise Canceling - Noise canceling microphone/input devices are required for high noise environments (85 dB (A) or above) and are preferred in all areas.

c. Loudspeaker/output devices :

1. Sidetone - The speaker's verbal input shall be in phase (not have a perceptible delay) with its reproduction as heard on the output device.
2. Audio equipment used to feed multiple channels into output devices shall maintain the frequency response uniformly (± 5 dB) over the bandwidth.
3. Headsets - If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities shall be capable of reducing the ambient noise level to less than 85 dB(A). Provisions shall be incorporated to furnish the same protection to those who wear glasses.

d. Use of De-emphasis - When transmission equipment employs pre-emphasis and peak-clipping is not used, reception equipment shall employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility (i.e., de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz).

e. Feed Back Noise - Positive feedback noise shall be controlled to the extent that normal voice communication is not adversely affected.

f. Earphone/Speaker To Microphone Feedback Isolation:

1. Sufficient electrical, mechanical, and acoustical isolation shall be provided to preclude feedback oscillations (squeal problems) or echo effects (no discernable unwanted voice echo to speaker).
2. Earphone/Speaker to microphone system loop gain shall be limited to less than 1.

9.4.3.3.3 Operator Comfort and Convenience Design Requirements

Requirements for operator comfort and convenience are provided below.

- a. Comfort - Communication equipment to be worn by a crewmember (e.g., headphones) shall be designed to preclude operator discomfort. Metal parts of the headset shall not come in contact with the user's skin.
- b. Hands-Free Operation - Operator microphones and headphones shall be designed to permit hands-free operation under normal working conditions.

9.4.4 Caution and Warning Displays

9.4.4.1 Introduction - N/A

9.4.4.2 Caution and Warning System Design Considerations - N/A

9.4.4.3 Caution and Warning System Design Requirements

9.4.4.3.1 Alarm Classification Design Requirements

Three alarm classifications are presented below. These are:

- a. Emergency (class 1 alarm).
- b. Warning (class 2 alarm).
- c. Caution (class 3 alarm).

9.4.4.3.1.1 Emergency Display Design Requirements

Requirements for the design of emergency displays are presented below.

- a. Definition of Class 1 Alarm - A life threatening condition requiring immediate attention. Predefined crew responses may be required prior to taking corrective action. Examples: cabin pressure decrease, fire/smoke, toxic atmosphere, impending collision.
- b. Annunciation Requirements:
 - 1. Each condition shall trigger a unique aural tone, (e.g., fire-siren, cabin pressure-klaxon).
 - 2. Tones and visual annunciation shall be heard and seen in any habitable area of the ACRV and the SSF.
 - 3. Illuminated visual annunciation shall indicate presence of specific emergency condition.
 - 4. Tone shall be resettable at all major control consoles/areas.

5. Corrective action information shall be available.

9.4.4.3.1.2 Warning Signal Design Requirements

Requirements for the design of warning signals are presented below.

a. Definition of Class 2 Alarm - Conditions that require immediate correction to avoid loss of major impact to mission or potential loss of crew. Examples: electrical bus loss, cooling loop failure, rapid loss of consumables.

b. Annunciation Requirements:

1. A warning signal shall trigger an identifiable warning tone and master warning light at all major control consoles/areas of the ACRV and the SSF.
2. Tone and light shall be reset only by crew action.
3. Message or light shall be provided to specify condition.
4. Method shall be provided to determine if condition returns within limits.
5. Corrective action information shall be available upon crew request.

9.4.4.3.1.3 Caution Display Design Requirements

Requirements for the design of caution displays are provided below.

a. Definition of Class 3 Alarm:

1. Conditions of a less time critical nature, but with the potential for further degradation if crew attention is not given. Example: heavier than normal consumable usage.
2. Messages that flag loss of redundant equipment such that a subsequent failure could result in a warning condition. Action is not necessarily required except that the effect of the loss in future activity planning must be considered. Example: loss of backup communication equipment.

b. Annunciation Requirements:

1. Caution displays shall trigger a general tone and light (different than class 2 tone/light) for a set time duration. This duration may be set differently for each caution condition.
2. Tone and light shall be extinguishable by crew action.
3. Data system message shall specify condition and corrective action at the discretion of the crew.
4. At least one crewmember shall always be available to receive a caution signal.

5. A method shall be provided to determine if condition returns within limits.
6. A method shall be provided to identify momentary out of limits condition.

9.4.4.3.2 General Caution and Warning System Design Requirements

General requirements for caution and warning systems (CWS) are provided below.

- a. CWS Recovery - The CWS shall be rapidly recoverable from a software system crash.
- b. CWS Test Limits - Permanent limit or test conditions shall be stored redundantly in such a way that they are protected from system crashes and single operator errors involved with temporary limit changes.
- c. System Failure - The system shall remain operable during and after major system failures (power, data, etc.).
- d. Sensor Changeout - Critical CWS sensors shall be accessible for changeout when feasible.
- e. System Status During Alarm - After an alarm is triggered, it shall be quickly determinable if the out-of-limit condition still exists and/or if a new out-of-limit condition occurs.
- f. CWS Suppression - The CWS shall allow alarms, due to predefined activities or conditions, to be screened or suppressed.
- g. Alarm Source - The source of an alarm due to any limit violation shall be easily determined (even if alarm condition is no longer present).
- h. Time History - The history of all alarms shall be maintained and shall be easily retrievable, with the time of occurrence noted.
- i. Alarm Classification - The approximate level of classification of an alarm shall be instantly apparent.
- j. CWS Status - After real-time modifications are made to CWS software, exact status shall be easily determined.
- k. CWS Baseline Limits - A return to the baseline (default) configuration of the CWS shall be easily enabled after a temporary modification or software "crash".
- l. Multiple Alarms - A single failure condition shall not cause a "waterfall" of related alarms. However, all out-of-limit conditions shall be retrievable by crewmembers.
- m. Existing Signals - Established and recognized audio alarm signals shall be used, provided they are compatible with the acoustic environment and the requirements specified herein. Standard signals shall not be used to convey new meanings.
- n. Priority - The CWS shall recognize the highest category of unacknowledged signal.

o. Disruptive Alarms:

1. All Class 1 through 3 alarms that would disrupt crew performance shall be capable of being easily downgraded to a redundant but non-disruptive alarm after its initial alerting function has been acknowledged. For example, an audio alarm might be downgraded to a non-disruptive visual signal that would be presented continuously until the alert condition no longer existed.

2. A disruptive alarm that requires manual shut-off shall not be used if the act of shutting it off would interfere with the corrective action required.

p. Alerting Function - CWS alarm signals shall have positive alerting characteristics under all operating conditions.

9.4.4.3.3 Visual Caution and Warning Display Design Requirements

Requirements for the design of visual caution and warning systems are presented below.

a. Master Alarm Light:

1. A master alarm light shall be provided in cases where caution, warning, or emergency lights have been located outside of the operator's 30 degree cone of vision.

2. Illumination of the master alarm light shall indicate that at least one or more caution, warning, or emergency lights have been energized.

3. The master alarm light and any applicable caution, warning, or emergency light(s) shall be energized simultaneously.

4. Master alarm status lights shall be visible to all operating personnel.

b. Advisory and Alerting - Displays such as multifunction displays, cathode ray tube displays, head-up displays, collimated displays and other visual display devices displaying simultaneous and integrated information shall advise or alert operating personnel to information that becomes critical within the display.

c. Extinguishing Signal Lights - Signal lights shall be extinguished by one or more of the following methods:

1. Restoration of a within-tolerance condition without remedial action or as a result of automatic switch-over.

2. Correction of the situation as a result of remedial action by the crew.

3. Performance of some action by the crew which is directly related to the controls of the affected system or component. This action indicates one or more of the following:

- a) An acknowledgement of the occurrence of the malfunction.
- b) The completion of indirect remedial action.
- c) The shutting down of the malfunctioning system or component.
- d. Unambiguous Signals - CWS information shall be presented unambiguously, identifying the actual problem.
- e. Color - The color of CWS indicator lights shall conform to the designation given in Paragraph 9.5.3.2 L.
- f. Brightness - Indicator lights shall be at least three times brighter than the other indicators on the same panel.

9.4.4.3.4 Audio Caution and Warning System Display Design Requirements

9.4.4.3.4.1 Audio Alarm Characteristics Design Requirements

Requirements for the design of audio alarm signals are provided below.

a. Frequency:

- 1. Range - The frequency range shall be between 200 and 5,000 Hz and, if possible, between 500 and 3,000 Hz. Frequencies below 500 Hz shall be used when signals must bend around obstacles or pass through partitions. The selected frequency band shall differ from the most intense background frequencies.
- 2. Spurious signals - The frequency of an alarm tone shall be different from that of the electric power employed in the system to preclude the possibility that a minor equipment failure may generate a spurious signal.

b. Intensity:

- 1. Compatibility with acoustical environment - The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas.
- 2. Compatibility with clothing and equipment - As applicable, audio signals shall be loud enough to be heard and understood through equipment or garments.
- 3. Discomfort - Audio alarm signals shall not be of such intensity as to cause discomfort. The limits established in paragraph 5.4.3 Acoustics Design Requirements shall not be exceeded.
- 4. Audibility - A signal-to-noise ratio of at least 20 dB shall be provided in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.

5. Pressure operated gain control switches to compensate for volume attenuation in underpressurized areas shall be provided.

c. Alerting Capability:

1. Attention - Signals with high alerting capacity shall be provided when the system or equipment imposes a requirement on the operator for concentration of attention. Such signals shall not, however, be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

2. Onset and sound pressure level - The onset of critical alerting signals shall be sudden, and at a sound pressure level as specified in b.4. above.

3. Headset - When the operator is wearing earphones covering both ears during normal equipment operation, the audio alarm signal shall be directed to the operator's headset as well as to the work area.

d. Discriminability:

1. Use of different characteristics - When several different audio signals are to be used to alert an operator to different types of conditions, discriminable difference in intensity, pitch, or use of BEATS and HARMONICS shall be provided. If absolute discrimination is required, the number of signals to be identified shall not exceed four.

2. Action segment - The identifying or action segment of an audio emergency signal shall specify the precise emergency or condition requiring action.

3. Critical signals - The first 0.5 second of an audio signal requiring fast reaction shall be discriminable from the first 0.5 second of any other signal that may occur.

4. Differentiation from routine signals - Audio alarms intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals, such as normal operation noises.

5. Prohibited types of signals - The following types of signals shall not be used as alarms where possible confusion might exist because of the operational environment:

a) Modulated or interrupted tones that resemble navigation signals or coded radio transmissions.

b) Steady signals that resemble hisses, static, or sporadic radio signals.

c) Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time.

d) Simple warbles that may be confused with the type made by two carriers when one is being shifted in frequency (beat-frequency-oscillator effect).

e) Scrambled speech effects that may be confused with cross modulation signals from adjacent channels.

f) Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (e.g., "bagpipes").

e. Masking Other Critical Channels - Audio alarm signals shall not interfere with any other critical functions or mask other critical audio signals.

9.4.4.3.4.2 Audio Alarm Control Design Requirements

Requirements for the design of controls for audio alarm devices are presented below.

a. Automatic or Manual Shut-Off - When an audio signal is designed to persist as long as it contributes useful information, a shut-off switch controllable by the operator, the sensing mechanism, or both, shall be provided, depending on the operational situation and personnel safety factors.

b. Automatic Reset - Whether audio alarm signals are designed to be terminated automatically, by manual control, or both, an automatic reset function shall be provided. The automatic reset function shall be controlled by the sensing mechanism which shall recycle the signal system to a specified condition as a function of time or the state of the signaling system.

c. Volume Control:

1. Automatic or manual - The volume (loudness) of an audio alarm signal shall be designed to be controlled by the operator, the sensing mechanism, or both, depending on the operational situation and personnel safety factors. Control movements shall be restricted to prevent reducing the volume to an inaudible level.

2. Ganging to mode switches - Volume controls may be ganged to mode switches to provide maximum output during mission phases in which intense noise may occur and to provide reduced volume at other times. Ganging shall not be accomplished if there is a possibility that intense noise may occur in an emergency situation during a mission phase in which the volume would be decreased below an audible level.

9.4.4.3.4.3 Verbal Alarm Signal Design Requirements

Requirements for the design of verbal CWS signals are presented below.

a. Nature of Signals - Verbal alarm signals shall consist of:

1. An initial alerting signal (non-speech) to attract attention and to designate the general problem.
2. A brief standardized speech signal (verbal message) which identifies the specific condition and optionally suggests appropriate action.

b. Intensity - Verbal alarms for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver.

c. Vocal Criteria:

1. Type of Voice - The voice used in recording verbal alarm signals shall be distinctive and mature.
2. Delivery style - Verbal alarm signals shall be presented in a formal, impersonal manner.
- d. Speech Processing - Verbal alarm signals shall be processed only when necessary to increase or preserve intelligibility, such as by increasing the strength of consonant sounds relative to vowel strength. Where a signal must be relatively intense because of high ambient noise, peak-clipping may be used to protect the listener against auditory overload.
- e. Message Content - In selecting words to be used in audio alarm signals, priority shall be given to intelligibility, ability to convey desired message, and conciseness in that order.
- f. Critical Verbal Alarms - Critical verbal alarm signals shall be repeated with not more than a 3 second pause between messages until the condition is corrected or overridden by the crew.

9.4.5 Advisory and Tutorial Displays

9.4.5.1 Advisory and Tutorial Design Requirements

9.4.5.1.1 Advisory Display and Annunciation Requirements

Requirements for the design of advisory displays are presented below:

- a. Definition of an Advisory Display - System initiated messages advising of a process status or other discrete event. Examples: Rendezvous solution complete, mass memory search for format in progress. Crew programmed reminder alerts keyed to time, orbit phase, bi-level state, parameter limit.
- b. Annunciation Requirements:
 1. No tones or lights shall be provided.
 2. Message shall accompany all alerts.
 3. A history of all messages shall be maintained and available for recall.
 4. Advisory displays shall be limited to specific workstations.

9.4.5.1.2 Tutorial Display and Annunciation Requirements

Requirements for the design of tutorial displays are provided below:

- a. Definition of a Tutorial Display - Messages denoting illegal keyboard syntax, or for assisting in proper completion of required inputs. These are limited to software configuration requirements.

- b. Annunciation Requirements - No tones/lights shall be used.

9.5 LABELING AND CODING

9.5.1 Introduction - N/A

9.5.2 Labeling and Coding Design Considerations - N/A

9.5.3 Labeling and Coding Design Requirements

9.5.3.1 Labeling Design Requirements

9.5.3.1.1 Labeling Standardization Design Requirements

Requirements for standardizing labeling are listed below.

- a. Standardization - To the extent practical, labeling shall be standardized between and within systems.
- b. Categories - Different labeling categories shall be distinct from one another (e.g., it shall be obvious with a quick glance that a label with operating instructions is not an emergency procedure or a stowage label).

9.5.3.1.2 Readability Design Requirements

The readability of labels and markings shall be maximized. The following requirements apply.

- a. Vibration, Motion, and Illumination - Labels and markings shall allow easy and accurate reading in the operational environment, which includes vibration, motion, and illumination considerations.
- b. Concise and Unambiguous - Labels shall be as concise and unambiguous as possible while still conveying the intended information.
- c. Language - Labels shall be written in the English language.
- d. Redundancy - Redundancy shall be minimized.
- e. Accuracy - Labels and markings shall provide the required accuracy of identification.
- f. Size - The size of labels and markings shall be appropriate for all distances from which they must be read.
- g. Illumination - Labels and markings shall be designed to be read at all expected illumination levels and color characteristics of the illuminant.
- h. Critical Function - The design of labels and markings shall take into account the criticality of the function to be labeled.

- i. Specular Reflection - The design of labels and markings shall minimize the effects of specular reflection on their readability. A matte or lusterless finish shall be used.
- j. Sharpness, Contrast, and Wear - Labels and markings shall be sharp, have high contrast, and not lose readability as a result of wear.
- k. Clutter - Labeling and markings shall be designed and placed so as to minimize visual clutter that could result in information overload.
- l. Iconic/Symbolic Labels - Iconic or symbolic labels shall be permitted.

9.5.3.1.3 Display Label Placement Design Requirements

Requirements for display label placement are given below.

- a. Orientation - All markings and labels shall be oriented horizontally to the common plane so that they may read quickly and easily from left to right (vertical orientation shall be avoided whenever possible).
- b. Display Labels - Labels identifying display functions shall be placed on the panel above the display.
- c. Curved Surfaces - Placement of labels on curved surfaces shall be avoided when possible.
- d. Visibility - Markings shall be located so that they are visible to crewmembers in the normal position of access or operation.
- e. Overhead Panels - On overhead panels, markings and labeling shall be oriented such that they appear upright when observed from the operational viewing angle.
- f. Clutter - Markings shall be spaced to avoid a cluttered appearance.
- g. Association Errors - The arrangement of markings on panels shall be such that errors of association of one marking or set of markings with adjacent ones shall not be possible.

9.5.3.1.4 Scale Marking Design Requirements

Requirements for the design of scale markings are provided below:

- a. Accuracy:
 - 1. Display range and readout accuracy shall not exceed the needs of the crew to manage the equipment for which the displays are provided.
 - 2. Scale markings shall not permit readout accuracies that are more precise than the accuracy of the input signal.

3. In general, scales that are to be read quantitatively to the nearest graduation mark shall be designed so that interpolation between graduation marks is not necessary. Interpolation, if required, shall be limited to one half the distance between minor graduation marks.

b. Interval Values:

1. The graduation intervals shall progress by 1, 5, or 2 units or decimal multiples thereof, in that order of preference.
2. The number of graduation marks between numbered graduation marks shall not exceed 9.

c. Scale Markings (High Luminance - above 1 ft-L):

1. The minimum width of major, intermediate, and minor marks shall be 0.32 mm (0.0125 in.).
2. The length of major, intermediate, and minor graduation marks shall be at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, and 0.09 in.), respectively.
3. The minimum distance between major graduation marks shall be 13 mm (0.5 in.).
4. Minor graduation marks may be spaced as close as 0.89 mm (0.035 in.), but the distance shall be at least twice the stroke width for white marks on black dial faces and at least one stroke width for black marks on white dial faces.

d. Scale Markings (Low Luminance - below 1 ft-L):

1. The minimum width of a major graduation shall be 0.89 mm (0.035 in.); the minimum width of an intermediate graduation shall be 0.76 mm (0.030 in.); and the minimum width of a minor graduation shall be 0.64 mm (0.025 in.).
2. The length of major, intermediate, and minor graduation marks shall be at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, and 0.10 in.), respectively.
3. The minimum distance between major graduation marks shall be 16.5 mm (0.65 in.).
4. Graduation marks shall be spaced a minimum of 1.5 mm (0.06 in.) between centerlines.

9.5.3.1.5 Alignment Marks/Interface Identification Design Requirements

Requirements for alignment marks and other interface identification are provided below.

a. Hardware Connectors

b. Orientation - When a piece of hardware requires a specific orientation that cannot be identified by alignment marks, arrows and/or labels shall be used to indicate the proper orientation.

- c. Color - Unless color coding is to be employed, alignment marks shall be lusterless white on dark colored hardware and lusterless black on light colored hardware.
- d. Identification - Interface identification shall be used to indicate the relationship between unattached items that are used together, except when this relationship is obvious.
- e. Tethered Equipment - Interface identification shall not be used for movable items tethered to a mating part (e.g., dust cap for an electrical connector, hinged lid for a stowage container, etc.)

9.5.3.1.6 Equipment Identification Design Requirements

Requirements for equipment identification are listed below.

- a. Equipment Marking - Equipment that must be located, identified, observed, or operated by a crewmember shall be marked with nomenclature that describes the function of the item and its pertinent interfaces. However, items whose use is obvious to the crew (e.g., food table, windows, etc.) are exempt from this requirement.
- b. Numbered Items - Multi-quantity items that require individual distinction but are not serialized shall be individually numbered.
- c. Serial Numbers - Multi-quantity items that are serialized shall display the serial number as part of the identification.
- d. Name Plates - Name plates depicting manufacturer's name, serial numbers, etc., shall not be mounted on the control or display surface area of any equipment.

9.5.3.1.7 Location and Orientation Coding Design Requirements

Requirements for location and orientation coding are listed below.

- a. Location and Orientation Designation - A system of location and orientation coding shall be established for the purpose of designating and locating crew interface items. The system shall be so designed as to permit a unilateral logical assignment of codes to items added or relocated.
- b. Location Maps - A map of location codes shall be provided at the entrances to a room or sub-volume where the coding scheme is not obvious to the crewmember.
- c. Location Code:
 - 1. All fixed crew interface items (e.g., equipment, control/display stations, stowage containers, connector panels, etc.) shall display a location code adjacent to the identification marking.
 - 2. Movable items that require a crew interface but are not stowed in a containment shall display a location code on a fixed surface adjacent to the item.

- d. Orientation Designation - When the orientation of the vehicle axes is significant to crew operation and is not obvious, axis designators shall be displayed on appropriate surfaces.

9.5.3.1.8 Operating Instruction Design Requirements

Requirements for the design and use of operating instructions are provided below.

- a. Location - Operating instructions shall be located on or near equipment whose operation is not obvious to a crewmember.
- b. Completeness - Operating instructions shall be complete enough to allow accurate task performance.
- c. Equipment Name - The instructions shall have the title of the equipment to be operated centered above the text (see Figure 9.5.3.1.8-1).
- d. Grouping - Instructions shall be grouped and titled by category (e.g., installation, removal, activation, calibration, etc.) if appropriate. (See example in Figure 9.5.3.1.8-1).
- e. Case - Instructional text shall use upper and lower case letters (See Figure 9.5.3.1.8-1).
- f. Title Selection - The titles of equipment, controls, displays, switch positions, and connectors shall be listed in upper case letters only. Care shall be taken to ensure that all title nomenclature is consistent with procedural handbooks and checklists.
- g. Required Tools - Instructions for removal of stowage items shall list the tools required, if any, prior to the instructional text. Markings shall be used to locate the fasteners to be removed if clarification is required.

9.5.3.1.9 Stowage Container Labeling Design Requirements

Requirements for stowage container labeling are provided below.

- a. Purpose - Stowage containers shall be labeled so that items are easy to find and return to place.
- b. Transparent - Where practical, containers shall be transparent, thus allowing identification of contents at a glance.
- c. Contents List - Each stowage container shall display a list of contents on its front surface visible to the crewmember. Items shall be listed one per line and launch quantities noted if greater than one.
- d. Label Revision - Provisions shall be made to permit in-flight revisions to, or replacement of stowage labels on all stowable containers.
- e. Individual Crew Items - Items allocated to a specific crewmember shall be identified on the listing with the user's title, name, or other coding technique.

SSMD

OPERATION

1. Obtain note pad
2. Place specimen on tray
3. MASS/ON/TEMP
4. RESET - press
5. Control lever - RELEASE (hold until counter stops)
6. Control lever - LOCK
7. Log reading on note pad
8. Repeat measurement for total of 3
9. MASS/OFF/TEMP - OFF
10. Control lever - LOCK (verify)
11. Remove specimen and log SSMD readouts on tag
12. Process specimen
13. If necessary clean tray and tie-down

CALIBRATION

1. Obtain SPI food log
2. Measure tray temp (M487 Digital Thermometer)
3. Log reading
4. MASS/OFF/TEMP - MASS
5. RESET - press
6. Control lever - RELEASE (hold until counter stops)
7. Control lever - LOCK
8. Log reading in Food Log
9. Repeat for a total of 5
10. Calib. points 0, 50, 100, 150, 250, 350, 500, 750, 900, 0
11. MASS/OFF/TEMP - OFF
12. Voice record data at any convenient time

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Reference: 1, Page 4.8-7

Figure 9.5.3.1.8-1 Operating Instructions

f. Subdivided Containers:

1. If a storage container is subdivided internally into smaller closed containers, the sub-containers shall carry a list of contents.
2. If a sub-container is open to view and its contents are obvious, it is exempt from this requirement.
3. If the available marking space on a sub-container is insufficient to display the complete content titles, a contents list shall be displayed elsewhere and clearly identified as belonging to the sub-container.
4. The specific contents of each sub-container and its code shall be listed on the front surface of its container or near it.

g. Similar Item Labeling - Containers with designated locations for placement of several similar items (e.g., socket wrenches in a tool kit) shall have each location identified with the title of the item stowed.

9.5.3.1.10 Failed/Expendable Item Design Requirements

Requirements for the labeling of failed/expended items are provided below.

- a. Failed Items - A method shall be provided for visually marking failed and expended items (e.g., equipment controls, displays, connectors, etc.) to indicate their unusable status. Color-coded labels with appropriate nomenclature (e.g., DO NOT USE) are preferred.
- b. Discardable Items - Items to be discarded after use shall display a unique marking on the item. Color-coded labels with appropriate nomenclature (e.g., DISCARD) are preferred, and the method of disposal shall be included when applicable.

9.5.3.1.11 Contingency Labels and Marking Devices Design Requirements
- N/A

9.5.3.1.12 Grouped Controls and Displays Design Requirements

Requirements for labeling of grouped controls and displays are provided below.

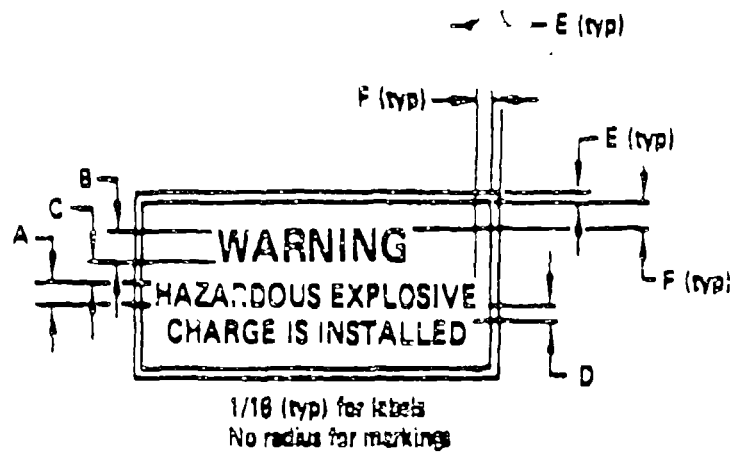
- a. Group Identification - Functional groups of controls shall be clearly identified (e.g., by common color, by boundary lines.)
- b. Labels of Functional Groups - Labels shall be used to identify functionally grouped controls and displays. Labels shall be located above the functional groups they identify.
- c. Boundary Lines - When a line is used to enclose a functional group and define its boundaries, the labels shall be centered at the top of the group, in a break in the line. The width of the line shall not be greater than the stroke width of the letters.

- d. Related Controls - When controls and displays must be used together in certain adjustments or activation tasks, appropriate labels shall indicate their functional relationships.

9.5.3.1.13 Caution and Warning Labels Design Requirements

Caution and warning labels are required for indicating potentially undesirable conditions. Requirements are provided below.

- a. Identification - Caution and warning labels shall identify the type of hazard and the action that would prevent its occurrence.
- b. Location - The caution markings shall be located in a position that permits sufficient opportunity for the crew to avoid the hazard.
- c. Immediate Action Controls - All controls, buttons, and small handles or levers requiring immediate access shall have their panel background colored in accordance with the applicable sub-section of Section 9.5.3.2; large handles or levers shall be similarly colored on the handle or lever itself.
- d. Emergency-Use Items:
 - 1. Emergency-use items (e.g., repair kits, emergency lighting, fire extinguisher, etc.) shall display a unique marking (EMERGENCY USE) surrounded by diagonal yellow and black stripes (see either on the item or adjacent to it).
 - 2. For items located within a storage container, the diagonal striping shall be applied to the door of the container and the titles of the emergency items shall be included on the marking instead of the words EMERGENCY USE.
- e. Warning Stripe Specification:
 - 1. Warning stripes shall be alternate yellow 33538 and black 37038 per FED-STD-595a. The black stripes shall have a width not less than 1.6 mm (0.065 in.) and the yellow stripes shall be at least two times the width of the black stripes.
 - 2. The striping shall be applied at a 45 degree angle rotated clockwise from the vertical.
 - 3. The striping shall begin and end with a yellow strip.
 - 4. The striping around a switch or button shall not be wider than 25 mm (1 in) or less than 3 mm (0.125 in).
 - 5. If one side of a switch or button has less than 3 mm (0.125 in) space, no striping shall be applied to that side.
- f. Label Specifications - Hazard identification labels shall use a letter size and spacing large enough to convey the warning (see Figure 9.5.3.1.13-1).



A - Text or minor lines of lettering	= A
B - Heading or major line of lettering	= 1.25A to 2A
C - Spacing between heading and text	= 0.65A to A
D - Spacing between lines of text	= 0.50A
E - Border width	= 0.60A
F - Background border	= A

Reference: 1, page 4.8-11

Figure 9.5.3.1.13-1 Letter Size and Spacing for Caution and Warning Labels

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9.5.3.1.14 Alphanumeric Design Requirements

9.5.3.1.14.1 Font Style Design Requirements - N/A

9.5.3.1.14.2 Punctuation Design Requirements

Requirements for punctuation marks used on labels are provided below.

- Use - The use of punctuation marks shall be kept to a minimum.
- Periods - Periods shall be omitted except when needed to preclude misinterpretation.
- Hyphens - Hyphens shall be avoided whenever possible.
- Parentheses and Ampersands - Parentheses and ampersands shall not be used on the display and control panel or other crew equipment.
- Slashes - The slash (/) shall be used in place of the words to indicate multiple functions.

9.5.3.1.14.3 Upper/Lower Case Design Requirements

Requirements for the use of upper and lower case lettering for labeling are provided below.

- a. Abbreviations - Lower case letters shall be used in abbreviations or symbols in which their use is the commonly accepted practice (e.g., He, pH, Hg, etc.).
- b. Operating Instructions - Equipment operating instructions shall use lower case for text and upper case for the first letter of a sentence, headings, titles of equipment, and references to control/display panel markings.

9.5.3.1.14.4 Titles Design Requirements

Panel titles, subtitles, and mode titles shall be spelled out when possible.

9.5.3.1.14.5 Special Character Design Requirements

Requirements for special characters are described below.

- a. Subscript and Superscript Size - Subscripts and superscripts shall be 0.6 to 0.7 times the height of associated characters.
- b. Subscripts - Numeric subscripts and upper case letter subscripts shall be centered on the baseline of associated characters.
- c. Lower Case Letter Subscripts - The base of lower case letters and the ovals of g, p, q, etc., shall be at the same level as the base of adjacent capital letters.
- d. Degree Symbol - The degree symbol shall be centered on an imaginary line extended from the top of the F or C symbols.
- e. Pound or Number Symbol (#) - The pound or number symbol shall be centered on an imaginary line extended from the top of the associated numerals and placed approximately two stroke widths away from them.

9.5.3.1.14.6 Character Height Design Requirements

Requirements for character height are presented below.

- a. Character Height - Character height depends on viewing distance and luminance level. At a viewing distance of 710 mm (28 in) the height of letters and numerals shall be within the range of values given in Figure 9.5.3.1.14.6-1.
- b. Variable Distance - For a distance (D) other than 710 mm (28 in), multiply the values in Figure 9.5.3.1.14.6-1 by $D/710$ mm ($D/28$ in.) to obtain the appropriate character height.

Markings	Character height	
	3.5 cd/m ² (1 ft-L) or below	Above 3.5 cd/m ² (1 ft-L)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	5-8 mm (0.20-0.31 in.)	3-5 mm (0.12-0.20 in.)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	4-8 mm (0.16-0.31 in.)	2.5-5 mm (0.10-0.20 in.)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	1.3-5 mm (0.05-0.20 in.)	1.3-5 mm (0.05-0.20 in.)

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Reference: 2, Page 121

Figure 9.5.3.1.14.6-1 Character Height - 710 mm (28 in) Viewing Distance

c. **Size Categories** - Where feasible and appropriate, characters used in labeling shall be graduated in size. To determine character height, all nomenclature on a label may be divided into three categories: titles, subtitles, and text. The nominal heights at a viewing distance of 710 mm (28 in) for each category shall be:

1. Titles, 5 mm (0.19 in).
2. Subtitles, 4 mm (0.16 in).
3. Text, 3 mm (0.12 in).

In general, when moving to the next larger character size, the character height shall increase by approximately 25 percent.

d. **Space Limitations** - The use of the same size letters and numerals for all categories on a label is acceptable for solving space limitation and clarity problems. In this case, the height of lettering and numerals shall be not less than 3 mm (0.12 in).

9.5.3.1.14.7 Character Width Design Requirements

Requirements for character width are given below.

- a. Letters - The width of letters shall preferably be 0.6 of the height, except the letter "I" which shall be one stroke in width, the letters "J" and "L" which shall be 0.5 of the height, the letter "M", which shall be 0.7 of the height, and the letter "W", which shall be 0.6 of the height.
- b. Numerals - The width of numerals shall preferably be 0.6 of the height, except for the numeral "4", which shall be one stroke width wider and the numeral "1", which shall be one stroke in width.
- c. Wide Characters - Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1.

9.5.3.1.14.8 Stroke Width Design Requirements

Requirements are listed below.

- a. Height-to-Stroke Ratio - Marking letters and numerals shall have a height-to-stroke ratio of 5:1 to 8:1, depending on the application.
- b. Transilluminated Background - Opaque markings on a transilluminated lighted background shall have a height-to-stroke ratio of 5:1 to 6:1.
- c. Transilluminated Markings - Transilluminated markings on a dark background or markings used on integrally lighted instruments shall have a height-to-stroke ratio of 7:1 to 8:1.
- d. General Purpose Illumination - Characters used on display panels and equipment when viewed under general purpose flood lighting or normal daylight conditions shall have a height-to-stroke ratio of 6:1 to 7:1.

9.5.3.1.14.9 Character Measurement Design Requirements

Requirements for determining character dimensions are presented below.

- a. Measurement - All letters and numeral measurement shall be made from the outside edges of the stroke lines for other than machine engraving on opaque surfaces.
- b. Engravings - For all mechanical engraving on opaque surfaces, the dimension controlling the size of letters and numerals shall be measured from centerline to centerline of the stroke.

9.5.3.1.14.10 Spacing Design Requirements

Spacing requirements for text and numerals are given below.

- a. Character Spacing - The spacing between letters within words and between digits in a multi-digit number shall be the approximate visual equivalent of one stroke width between two straight-sided letters such as H and I. (This requirement is intended to accommodate the normal

commercial typographical practice of spacing letters to achieve a constant visual continuity. This permits close spacing of open letters such as C and T to avoid large apparent gaps).

b. Word Spacing - The spacing between words shall be the approximate visual equivalent of the letter W between two straight-sided letters such as N and F.

c. Line Spacing:

1. The spacing between lines of related text shall be 0.5 of upper case letter height.
2. Spacing between headings and text shall be 0.6 to 1.0 of upper case letter height.

9.5.3.2 Coding Design Requirements

Requirements for the implementation of various types of coding are presented below.

a. General Coding Requirements:

1. Standardization - The application of coding techniques shall be consistent within and between systems.
2. Clutter - Coding shall only be used where useful, as excessive coding can have the negative effect of adding to visual clutter.
3. Decrements - Coding shall not reduce legibility or increase transmission time.
4. Common Usage - Codes shall conform to conventional population stereotypes and general user expectations when these exist.
5. When feasible, meaningful codes shall be used rather than arbitrary codes. For example, use M for male and F for female rather than 1 for male and 2 for female.

b. Brightness Coding:

1. Brightness coding shall be employed to differentiate between an item of information and adjacent information.
2. No more than three levels of brightness shall be used. Each level shall be separated from the nearest by at least a 2:1 ratio.

c. Size Coding:

1. Symbols - Where size difference between symbols is employed, the major dimensions of the larger shall be at least 150% of the major dimensions of the smaller with a maximum of three size levels permitted.
2. Controls - No more than three different sizes of controls shall be used in coding controls for discrimination by absolute size. Controls used for performing the same function on different items or equipment shall be the same size.

d. Pattern Coding - Pattern coding shall be used to differentiate areas of interest to the observer (e.g., the normal, warning, and danger operating zones of a scale), and reduce operator search time.

e. Location Coding - Controls associated with similar functions shall be in the same relative location from panel to panel.

f. Shape Coding - Shape coding of controls shall be used to improve their identifiability through both the visual and tactile senses. Requirements are listed below.

1. Ease of operation - The coded feature shall not interfere with ease of control manipulation.

2. Position and orientation independence - Shapes shall be identifiable and differentiable by the hand regardless of the position and orientation of the control knob or handle.

3. Mounting - Shape coded knobs and handles shall be positively and non-reversibly attached to their shafts to preclude incorrect attachment when replacement is required.

g. Underlining, Bold Face, Italics - Coding techniques shall be used when it is necessary to direct a reader's attention to a particular element of alphanumeric text. These techniques shall include, but not be limited to, underline, bold face type, and italics.

h. Flash Coding:

1. Use - The use of flashing lights shall be minimized, and used only where immediate attention is required.

2. Flash rate:

- a) No more than 2 flash rates shall be used.

- b) Where one rate is used, the rate shall be between 3 and 5 flashes per second.

- c) Where two rates are used, the second rate shall be less than 2 per second.

3. Duty cycle - Flashing lights shall have approximately equal amounts of ON and OFF time.

4. Simultaneous signals - Flashing lights which could be simultaneously active shall have synchronized flashes.

5. Failure indication - If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily.

i. Color Coding - Color identification numbers used below are per FED-STD-595.

1. Color difference - Only one hue within a color category (e.g., reds, greens) shall be used in a given coding scheme, and that color shall always be associated with a single meaning.

2. Number of colors - No more than 9 colors, including white and black, shall be used in a coding system.

3. Ambient light:

- a) Color coding shall be compatible with anticipated ambient lighting throughout the mission.
- b) Color-coding shall not be used as a primary identification medium if the spectral characteristics of ambient light during the mission, or the operator's adaptation to that light, varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light.

4. Familiar color meaning - Color coordinates and color temperature which are consistent with common usage and existing standards with respect to application are listed below. All color coordinates for transilluminated lighting are per CIE (Commission International de l'Eclairage Coordinates Chart Chromaticity Diagram 1931). See Figure 9.5.3.2-1 for CIE Chromaticity Diagram and Figure 9.5.3.2-2 for Relative Kelvin Temperature Equivalence.

- a) Red #21105 - Emergency, warning, and master alarm lights; safety controls; critical controls requiring rapid identification; emergency shutdown; control panel outline of a functionally critical emergency nature. Transilluminated devices shall have coordinates of $x=.633 (+/- .03)$ $y=.255 (+/- .03)$.

(Note: Under ambient red lighting, use orange-yellow and black striping.)

- b) Yellow #33538 - Caution; emergency exits; safety controls associated with emergencies of a less critical nature. Transilluminated devices shall have coordinates of $x=.455 (+/- .03)$ $y=.550 (+/- .03)$.

- c) Yellow #33538 with black #37038 stripe - Immediate access; exit releases.

- d) Orange #32246 - Hazardous moving parts; machinery; start switches, etc.

- e) Green #14187 - Important and frequently operated controls having no urgent or emergency implications. Transilluminated devices shall have coordinates of $x=.155 (+/- .05)$ $y=.750 (+/- .05)$. Alternatively, for transilluminated devices, a wave length of 520nm is acceptable.

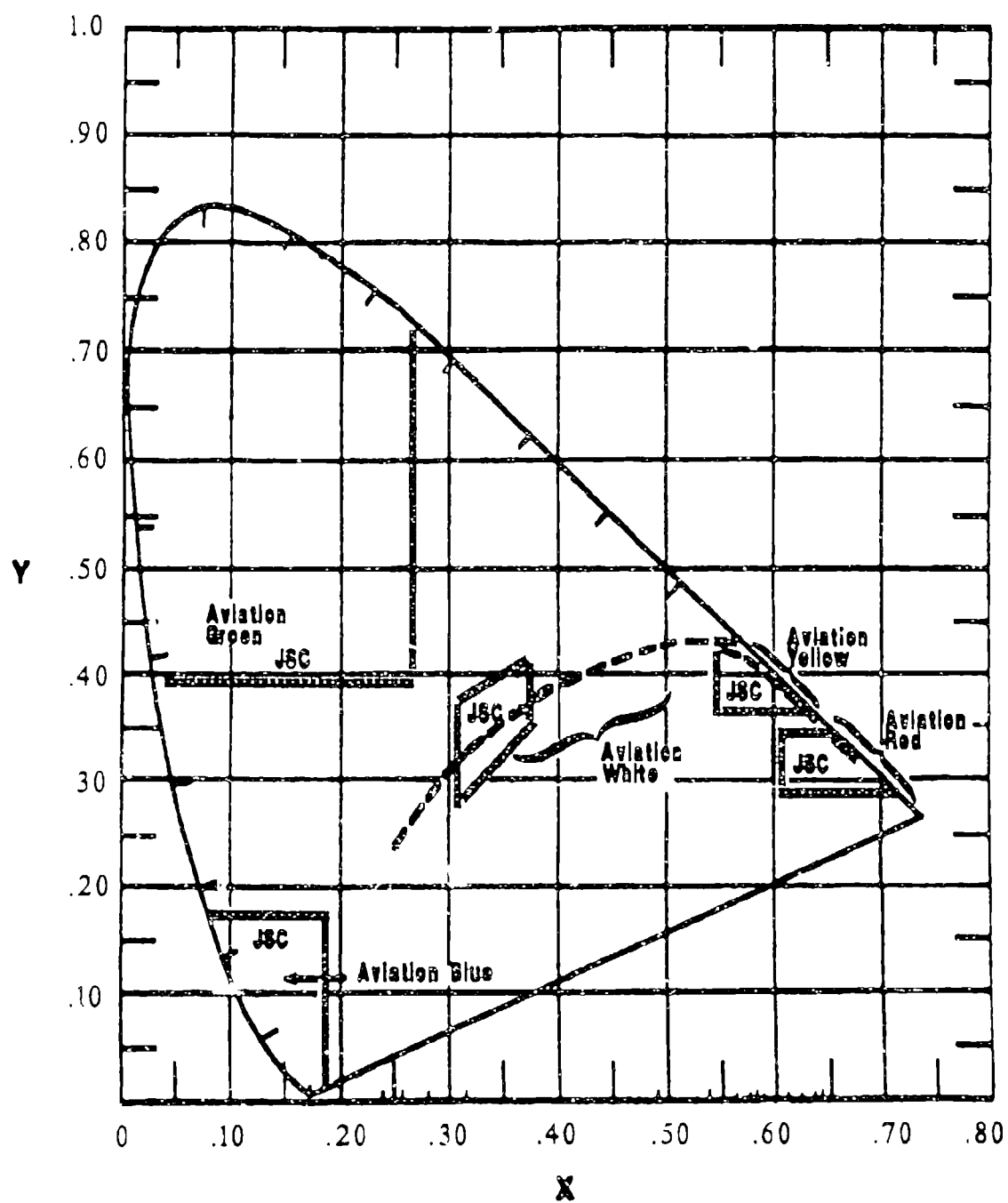
- f) Green (Sage) #14260 - First aid and survival.

- g) Blue #25102 - Advisory (not recommended for general use).

- h) Purple #37142 (magenta) - Radiation Hazard.

- i) White - Advisory (for transilluminated devices only) - Transilluminated devices shall have coordinates of $x=.360 (+/- .03)$ $y=.360 (+/- .03)$.

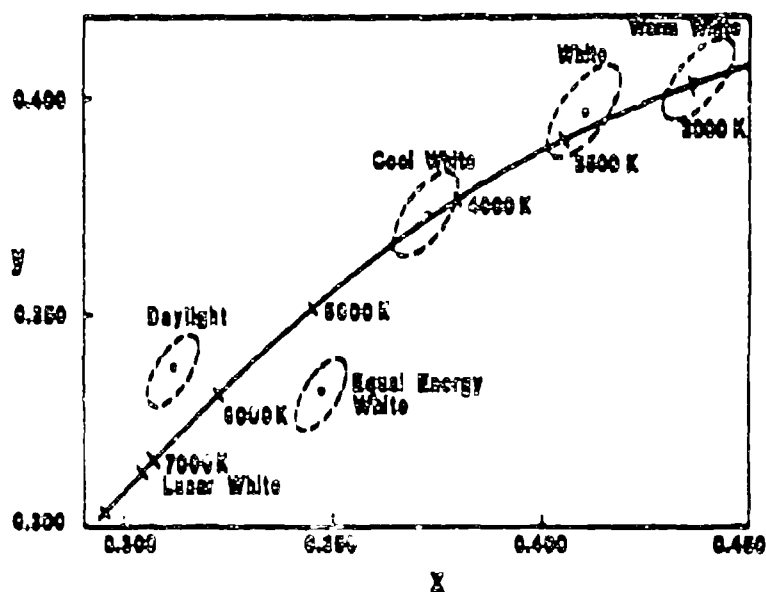
5. Color deficiency - To avoid confusion by color-deficient observers, do not use the color green if the color scheme uses more than six colors. If six or fewer colors including green #14260 and yellow are used, yellow #23655 shall be substituted for #33538. Red #11302 and blue #15177 may also be used; however, do not use red and green within the same complement.



Reference 389, page 5-9

Figure 9.5.3.2-1 CIE Chromaticity Diagram

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Reference: 389, page 5-18

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Figure 9.5.3.2-2 Relative Kelvin Temperature Equivalence (White Light)

6. Placards - The preferred markings and background color for placards are listed below.

<u>Markings</u>	<u>Background</u>
White	Black
Black	Yellow
Black	White
Yellow	Blue
White	Red
Blue	Yellow

7. Zone markings - On indicators where zone markings are used to indicate various operating conditions, the following requirements shall apply.

- a) Primary colors shall be limited to red, yellow, orange, and green consistent with color selection criteria given above.

- b) Zone markings shall be applied and located in a manner that facilitates easy removal.
- c) Zone markings shall not interfere with the reading of quantitative markings.
- d) When color is used to zone mark, the color shall be applied so that its meaning is consistent across applications.

8. Color Contrast - An important factor to consider when selecting colors is the contrast between various colors. This is necessary to ensure that each color is easily discriminated from the others. Although contrast is an important consideration, it should not be used without regard to other important factors such as convention or standard, inherent meaning, and consistency across displays.

a) The following color list shall be used to select colors that contrast maximally with the color just preceding it and satisfactorily with the earlier colors in the list. Colors (1) through (9) yield satisfactory contrast for red-green deficient as well as color - normal crewmembers. The remaining 13 are useful only for color-normal crewmembers.

- (1) White.
- (2) Black.
- (3) Yellow.
- (4) Purple.
- (5) Orange.
- (6) Light blue.
- (7) Red.
- (8) Buff.
- (9) Gray.
- (10) Green.
- (11) Purplish pink.
- (12) Blue.
- (13) Yellowish pink.
- (14) Violet.
- (15) Orange-yellow.
- (16) Purplish red.

(17) Greenish yellow.

(18) Reddish brown.

(19) Yellow-green.

(20) Yellowish brown.

(21) Reddish orange.

(22) Olive green.

b) Color contrast shall be selected in conjunction with color conventions and standards, inherent meaning, and consistency across displays.

9.6 USER-COMPUTER INTERACTION

9.6.1 Introduction - N/A

9.6.2 Data Display

9.6.2.1 Design Considerations for Data Display - N/A

9.6.2.2 Design Requirements for Data Display

a. Stand Alone - In general, data displays shall convey enough information to allow the user to interpret the data without referring to additional sources.

b. Shared Displays - If a single display monitor is used to display different categories of information alternately, none of the categories shall require continuous or concurrent monitoring.

9.6.2.3 Text

9.6.2.3.1 Design Considerations for Text - N/A

9.6.2.3.2 Design Requirements for Text

Text shall be presented using upper and lower case letters.

9.6.2.4 Tables

9.6.2.4.1 Design Considerations for Tables - N/A

9.6.2.4.3 Design Requirements for Tables

- a. Titles - All tables shall have a concise, descriptive title. Titles shall have a consistent location on tables.
- b. Labels - Each group of data in a table shall have a concise, descriptive, label that is separated from other characters and can easily be identified as the label.
- c. Consistent Widths of Characters - The fonts and widths of numeric characters shall be consistent within a table. Highlighting of numeric characters by means of italics or bolding shall not change the width of numeric characters. Differences in fonts and/or widths of alphabetic characters within a table shall not affect column or row size or spacing.
- d. Grouping - All displayed data necessary to support a user activity or sequence of activities shall be grouped together.

9.6.2.4.3 Matrix Tables

9.6.2.4.3.1 Design Considerations for Matrix Tables - N/A

9.6.2.4.3.2 Design Requirements for Matrix Tables

- a. Use - Matrix tables shall be used to present row-column data.
- b. Arrangement - Data in matrix tables shall be displayed in a left-to-right, top-to-bottom array. Alphanumeric data shall be left justified; numeric data shall be arranged with decimal points aligned vertically. (If a number does not have a visible decimal point, the decimal point shall be assumed.)
- c. Column Order - Material most relevant to the user or most frequently used shall be in the left column and shall progress to the least relevant in the far right column.
- d. Labels - Labels for the row variables shall be located in the left-most column; labels for the column variables shall be located in the top row. When a column extends over more than one "page" vertically (i.e., the user has to scroll or page to continue reading the column), the same column labels shall be displayed from "page" to "page". Similarly, when a row extends over more than one "page" horizontally (i.e., the user has to scroll or page to continue reading the row), the same row labels shall be displayed from "page" to "page".
- e. Readability - In tables with many rows or columns, a blank line, dots, or other distinctive feature shall be inserted after every fifth row or column as appropriate to help maintain one's place across columns or across rows.
- f. Organization of Rows and Columns - When possible, rows and/or columns in a table shall be arranged in a systematic order (e.g., chronologically, alphabetically, sequentially, by magnitude, by importance, or according to function).
- g. Discriminable rows and columns - Each column shall be discriminable from every other column by means of a physical cue, such as sufficient blank space or a line. Similarly, all rows shall be discriminable from one another by means of physical cues.

9.6.2.4.4 Functional Area Tables

9.6.2.4.4.1 Design Considerations for Functional Area Tables - N/A

9.6.2.4.4.2 Design Requirements for Functional Area Tables

- a. Use - A functional area table shall be used to display related data that has a less regular structure than a matrix. The data are organized into functional groups, similar to a completed data form.
- b. Group size - Related data shall be displayed in groups which subtend five degrees of visual angle or less. The groups shall be visually distinct from one another.
- c. Density - The ratio of filled display character spaces to the total number of character spaces shall not exceed 30% under nominal operating conditions

9.6.2.5 Graphics

9.6.2.5.1 Design Considerations for Graphics - N/A

9.6.2.5.2 Design Requirements for Graphics

- a. Use - Types of graphical displays include icons, schematics, data graphs, maps, flow charts, and pictures. Graphical displays shall be used when they will convey information to the user more clearly, effectively, or quickly than other formats. For example, graphics may be used as follows:
 - 1. A statistical data graph is appropriate when users need to monitor changing data, to scan a data set or sets quickly, to compare multiple sets of data, or to see trends in data.
 - 2. A flowchart is appropriate when users need to follow a sequence of events that involves logical branching or to observe the temporal order of events.
 - 3. A schematic is appropriate when users need to identify both the elements of a system and the spatial/temporal organization of those elements.
 - 4. A map is appropriate when users need to determine spatial relations between objects.
- b. User control - The user shall have the ability to change various physical features of a graphic to enhance his or her viewing capability, including enlarging and reducing the graphic or a subsection thereof, increasing the amount of detail (if additional detail is available, e.g., in a system schematic), and selecting different orientations or reference points (especially for maps and schematics).
- c. Simplicity - Graphical displays shall maintain the visually simplest display consistent with their function.

d. Directing the User to the Important Data - A graphical display shall direct the user's attention to the critical data. For example, users will notice heavier lines before lighter ones; brighter colors are detected before dim ones; larger bars are detected before slender ones. Use of these rules of thumb, as well as the use of coding techniques, will make for graphic displays that direct the user's attention to the desired location.

e. Identification of Graphic Displays - All graphic displays shall have unique, meaningful titles by which users can identify and access the display.

f. Identification of Elements in Graphics - All elements in graphic displays (including objects in a schematic, geographical locations in a map, and axes in a data graph) shall be identifiable and discriminable by the user. The two most prominent techniques for providing cues for identification are labeling and symbols.

1. Labels shall be in close proximity to the object that they identify, but shall not obscure the element.

2. In addition to or in place of labels, symbolic coding (e.g., texture, color, or shape) shall be used when appropriate to aid users in identifying elements of graphical displays. Symbolic codes shall be accompanied by legends that provide the symbol and its referent.

9.6.2.6 Coding

9.6.2.6.1 Design Considerations for Coding - N/A

9.6.2.6.2 Design Requirements for Coding

a. Highlighting - Highlighting (display coding which serves only to call the user's attention to a feature of a display) shall be used only for important information (e.g., out-of-limit conditions). When conditions change and an item that was highlighted is no longer important (e.g., after an out-of-limits condition has been corrected), that item shall no longer be highlighted. The specific highlighting technique used (e.g., reverse video, brightness contrast, boldness contrast, underlining, or blinking) shall not have a detrimental impact on the user's perception of the display.

b. Grouping - Coding shall be used to group functionally similar information and to indicate membership in a common group. Grouping allows users to perceive a large screen as consisting of smaller identifiable pieces. Spatial distance and shape coding are particularly powerful grouping techniques.

1. Grouping of information shall be accomplished by spatial distance, shape coding, lines, color coding or other means consistent with the application.

2. Displays with high information density shall have an intermediate number of groups. The preferred range for number of groups is 19-40.

c. Symbols - Coding by means of graphic symbols, shapes, or color shall be a key method used to communicate the specific meaning of an element of a display to a user. The choice of a symbol shall not contradict highly overlearned associations (e.g., the use of red as a symbol for stop or danger and the use of an octagonal shape for stop).

1. As a symbolic code, color shall be redundant with at least one other coding technique.
2. Users shall have access to the referent for every symbol.

9.6.2.7 Windows

9.6.2.7.1 Design Considerations for Windows - N/A

9.6.2.7.2 Design Requirements for Windows

- a. **Perceptual Characteristics of Windows** - Windows are subdivisions of displays in which one functionally-related set of information is displayed. Windows shall be perceptually distinct from the rest of the display.
- b. **Types of Windows** - Users shall be able to distinguish among different types of windows based on the perceptual characteristics of the window. Window types can be organized in a hierarchy based on their function: Open vs. Closed windows, where the user has perceptual and functional access only to the open window; Open windows can be Active or Inactive, where the active window contains an on-going activity, either user-maintained (e.g., a command language dialogue) or system-maintained (e.g., control of an ACRV subsystem by an expert system); Active windows can be an Interactive window (also known as the "listener") or a Noninteractive window, where the Interactive window is the one in which user actions have their effect.
- c. **Window Titles** - A brief, unique, and descriptive title shall be positioned in a consistent and highly visible location for each window. The user shall be able to use that title in accessing the window.
- d. **Multiple Windows** - When multiple windows are open simultaneously, with the exception of caution & warning information, the system shall not overwrite the active window(s).

9.6.2.8 Design Requirements for Format

- a. **Consistency** - Display formats shall be consistent within a system.
 1. When appropriate for users, the same format shall be used for input and output.
 2. Data entry formats shall match the source document formats when feasible and efficient for user performance.
 3. Recurring data fields within a system shall have consistent names and shall have consistent relative positions within displays.
- b. **Standardization** - The content of displays within a system shall be presented in a consistent, standardized manner.

c. Information Density:

1. Information density shall be held to a minimum in displays used for critical tasks.
2. A minimum of one character space shall be left blank vertically above and below critical information, with a minimum of two character spaces left blank horizontally before and after.

d. Selectable data display - Only data essential to the user's needs shall be displayed. The system shall permit the user to access any data at any time.

e. Readily Usable Form - Data presented to the user shall be in a readily usable and readable form such that the user does not have to transpose, compute, interpolate, or mentally translate into other units, number bases, or languages.

f. Order and Sequences - When data fields have a naturally-occurring order (e.g., chronological), such order shall be reflected in the format organization of the fields.

g. Extended Alphanumerics - When five or more alphanumeric characters without natural organization are displayed, the characters shall be grouped in blocks of three to five characters, separated by a minimum of one blank space or other separating character, such as a hyphen or slash.

h. Comparative Data Fields - Data fields to be compared on a character-by-character basis shall be adjacent. Relative position shall maximize ease of comparison.

i. Labels and Title:

1. Each individual data group, message, or window shall contain a descriptive title, phrase, word, or similar identifier to designate the content of the group or message.
2. Labels and titles shall be located in a consistent fashion adjacent to their referent; the relation between the label or title and referent shall be clearly visible.
3. Labels and titles shall be emphasized to facilitate user scanning and recognition. The technique used for emphasis (e.g., highlighting, see Section 9.6.3.1.4.a) shall be easily distinguishable from that used to highlight or code emergency or critical messages. Labels and titles shall not be confusable with data.
4. The physical features and wording of labels and titles shall be designed to avoid confusion as to whether the label is for a data entry field, a control option, a guidance message, or other displayed materials.
5. Labels and titles shall be unique to avoid confusions between labels.
6. When presenting a list of user options, the label shall be descriptive of the contents of the list and relevant to the task being performed by the user.

j. Identifying Location in Sequence of Displays - Cues shall be provided to the user to identify the currently displayed page and the total number of pages of a multiple page display (e.g., in a text file, the second page of a five page file might be labeled Page 2 of 5).

k. Abbreviations and Acronyms:

1. Information shall be displayed in plain concise text wherever possible.
2. Abbreviations and acronyms shall be standardized.
3. Abbreviations shall be distinctive to avoid confusion.
4. A single word shall have no more than one abbreviation.
5. No punctuation shall be used in abbreviations.
6. Definitions of all abbreviations, mnemonics, and codes shall be provided on-line at the user's request.

l. Number System - When numeric data are displayed or required, such data shall be in the decimal number system by default. Users shall have the ability to change the number system according to their task demands.

9.6.2.9 Information Display Rate

9.6.2.9.1 Design Considerations for Information Display Rate - N/A

9.6.2.9.2 Design Requirements for Information Display Rate

a. Information Display Rate - The information display rate shall not exceed human perception, comprehension, or response capabilities.

b. Update Rate:

1. The rate of update of information within a display shall be a function of both task requirements and user capabilities.
2. The rate of update of information shall not exceed the user's ability to perceive changes in values of parameters.
3. For slowly changing data, the system shall aid the user in attending closely to the display and in eliminating the need for extended fixation of the display.
4. Items requiring dynamic visual acuity on a graphic display shall not move faster than 60 degrees of visual angle per second, with 20 degrees per second preferred.

c. Display Freeze:

1. A display freeze mode shall be provided to allow close scrutiny of any selected display that is updated or advanced automatically by the system.
2. An option shall be provided to allow the user to either resume the update of information from the point at which the display was frozen or at the current real-time point.
3. An appropriate label or iconic symbol shall be provided to indicate to the user that the display is in the freeze mode.

d. System Response Time - Whenever possible, the time for the system to respond to a user command or request shall not exceed 2 seconds.

e. Keystroke Echo Response Time - Whenever possible, keystroke echo response time shall not exceed 0.1 second.

9.6.3 Real-Time Interaction

9.6.3.1 User-Computer Dialogues

9.6.3.1.1 Design Considerations for User-Computer Dialogues - N/A

9.6.3.1.2 Design Requirements for User-Computer Dialogues

a. Dialogue Type - The choice of the type of dialogue between the user and computer (e.g., command language, menus, data forms, direct manipulation) shall be compatible with user characteristics and task requirements. The human-computer dialogue for any task shall allow users to execute commands in terms of the functions to be performed without concern for internal computer data processing, storage, or retrieval mechanisms.

b. Multiple dialogues - To the greatest degree possible, users shall be able to input commands to the system using any of the available dialogue types and shall be able to switch between dialogue types within a task sequence.

c. User Viewpoint - User-computer dialogue techniques shall reflect the user's point of view such that the commands are logically-related to the user's conception of what is being done.

d. Feedback from commands:

1. When the completion of a command results in a consequence that is perceptible to the user, the completion of the commanded action shall be the only necessary feedback.
2. Rather than simply rejecting the entry, the system shall permit users to correct errors in commands, where feasible.

3. When the completion of a command results in a consequence that is not visible to the user, the system shall provide explicit feedback to the user that the command was completed. The feedback shall be in the form of a message that describes the actions that resulted from the command in simple, direct, positive language.

e. Arm-Fire Sequence for Critical Commands - Users shall have to confirm that they want to perform a critical, potentially hazardous, or potentially destructive command (including commands that would destroy stored data) before the system will execute it. The confirmation request from the system to the user shall be positive, simple, and direct. User actions to enable/arm and execute such functions shall consist of two separate and distinct commands, not repeat of a single command.

9.6.3.1.3 Command Language

9.6.3.1.3.1 Design Considerations for Command Language - N/A

9.6.3.1.3.2 Design Requirements for Command Language

a. Use - All users shall always have access to the command language. Additionally, the command language is especially well suited for

1. Tasks with an elaborate interaction between the user and system.
2. Highly trained, frequent system users.

b. Standardization - The functionality, design, and operation of the command language shall be standard. The standardization of the language shall include the lexicon, semantics, and syntax.

c. Command Language Terms - To the greatest degree possible, the meaning of terms in the command language shall correspond to English and be conveyed in a form such that additional resources are not required to interpret the message. The terms in the command language shall describe actions, objects, prepositions, and the attributes of actions or objects.

d. Command Language Syntax - The structure of the command language shall resemble the structure of English as closely as possible.

e. Distinctiveness - Command language terms shall be perceptually and semantically distinct from one another.

f. Punctuation - The command language shall contain a minimum of punctuation or other special characters.

g. Truncation - The user shall be able to enter the full command name or the system-specific truncated form. Truncated forms may consist of unique partial command terms, function keys, and command keystrokes.

h. Command Area - Commands shall be entered and displayed in a standard command area in a consistent location on all displays.

- i. Alternative Constructions - If users input alternative syntax or synonymous command language terms, the system shall aid the user in completing the command correctly.

9.6.3.1.4 Design Requirements for Command Keystrokes

- a. Uses - Command keystrokes (i.e., the use of a limited number of keystrokes combined with pressing a Command Key to access a command language term) shall be used primarily in cases where speed of command inputs is important. Other dialogue techniques shall be available, as appropriate.
- b. Consistency across applications - The structure and meaning of keyboard commands shall be consistent across applications.

9.6.3.1.5 Design Requirements for Function Keys - N/A

9.6.3.1.6 Menus

9.6.3.1.6.1 Design Considerations for Menus - N/A

9.6.3.1.6.2 Design Requirements for Menus

- a. Menu Item Selection:

1. The user shall be able to select a menu item with minimal activity.
2. When selection is to be accomplished by cursor placement on the to-be-selected item, the system shall aid the user in cursor placement. For example, for a permanent menu, the cursor would be placed on the most likely option, usually the first position.
3. Where design constraints do not permit cursor placement, a standard input area shall be provided for the user to key the selected option code.

- b. Presentation of Menu Items - Menu items shall be presented in a list format. Each menu item, along with any associated information (e.g., selection codes and descriptors), shall be displayed on a single line.

- c. Organization of Menu Items - Menu items shall be organized in a logical order (e.g., similarity of function, expected frequency of use, temporal ordering of the task). If no logical basis exists for ordering items, an alphabetical order shall be used.

- d. Coding of Menu Items:

1. When users have the capability to select a menu item by means of a coded entry, the code associated with the menu item shall be indicated on the display in close spatial proximity to the menu item.
2. Codes used to select menu items shall be related to the menu item so that users do not have to learn arbitrary codes.

3. If menu items are selectable by means of keystrokes, the arrangement of the keystrokes and menu shall be compatible.
- e. **Selectable Items Discriminable From Nonselectable Items** - Menu items that are available to be selected by the user shall be visually different from menu items that are not available in a given application or step in a task.
- f. **Format Consistency** - Menu formats shall be consistent throughout the system.
- g. **Menu Availability** - Menus shall be readily available to the user at all times.
- h. **Movement Through Menu Hierarchies:**
 1. The user shall have the capability to traverse menu hierarchies forward and backward.
 2. If several levels of menu hierarchy are presented, the user shall be able to move from one level to any other level without having to step through multiple menu level.
 3. The system shall provide visual cues that indicate the path that the user has travelled through a hierarchy of menus.
- i. **Feedback:**
 1. When a menu item is selected, an immediate indication that the intended item was selected shall be given. This indication shall not be confusable with other kinds of display coding.
 2. When selection of a menu item results in a continuing condition (e.g., turning on a pump which stays on until commanded to be shut off), a visual indication, clearly associated with the specific menu item, shall be provided to the user during the time that the condition continues.
- j. **Types of Menus** - Menus shall be available either as permanent menus or as user-requested menus ("user-requested menus" are menus which are present only when the user specifically asks for them, e.g., pop-up or pull-down menus). The type of menu shall be a function of the task requirements.

9.6.3.1.6.3 Permanent Menus

9.6.3.1.6.3.1 Design Considerations for Permanent Menus - N/A

9.6.3.1.6.3.2 Design Requirements for Permanent Menus

Permanent menus shall be used when:

- a. The user needs to see the menu items throughout a task.
- b. The user needs to examine every option in detail.

- c. The user does not have the ability to request that a menu be displayed (e.g., in the absence of a pointing device).
- d. The use of a user-requested menu would obscure information needed for a task.

9.6.3.1.6.4 User-Requested Menus

9.6.3.1.6.4.1 Design Considerations for User-Requested Menus - N/A

9.6.3.1.6.4.2 Design Requirements for User-Requested Menus

- a. Use - User-requested menus shall be used when:
 - 1. Display space is limited.
 - 2. Users need to see the menu items only when selecting them.
 - 3. Information required by the user would not be obscured by the menu.
- b. Menu design:
 - 1. The height of a menu bar (used to permit the user to request a menu) shall be sufficient to contain standard text characters which serve as the menu labels.
 - 2. Menu labels on the menu bar shall be brief, descriptive of the contents of the menu, physically separated from other menu labels, and semantically distinctive from other menu labels.
 - 3. Menu bars shall be placed in a consistent location in all displays.
 - 4. The organization of categories across the menu bar shall be logical (e.g., according to function or frequency of use).
- c. Activation - User-requested menus shall be displayed only after a single, specific action by the user. After the menu option has been selected, the menu shall revert to its hidden state.

9.6.3.1.7 Direct Manipulation

9.6.3.1.7.1 Design Considerations for Direct Manipulation - N/A

9.6.3.1.7.2 Design Requirements for Direct Manipulation

- a. Philosophy of Direct Manipulation - In the direct manipulation interface, the user shall be able to manipulate data structures or objects directly by physically interacting with their graphical representation

b. Features of Direct Manipulation - The direct manipulation interface shall have the following characteristics:

1. The objects of interest have continuous graphical representations (e.g., as icons and windows).
2. The users accomplish functions by means of physical actions with the objects instead of by language-based commands. Two primary physical actions are selecting an object and moving an object.
3. Operations are rapid, incremental, and reversible. The impact of an operation on the object of interest is immediately visible.

c. Use - Direct manipulation shall be among the dialogue techniques used for tasks.

1. Users have different languages.
2. The task objects and actions lend themselves to iconic representation.
3. Users are not highly practiced with the task.

9.6.3.1.7.3 Icons

9.6.3.1.7.3.1 Design Considerations for Icons - N/A

9.6.3.1.7.3.2 Design Requirements for Icons

a. Icon Design :

1. The icon shall pictorially represent the object or action. (An icon is a pictorial, pictographic, or other symbolic representation of a software object or an action by the system. A user's direct manipulation of the icon is equivalent to manipulating the software object or executing the system action.)
2. Icons shall be identifiable and discriminable.
3. Icons that the user can select shall be sufficiently large enough to minimize selection time and errors.
4. Icons shall be simple, closed figures.
5. Icons shall be accompanied by text labels which correspond to the term from the command language that describes the same object or action. The text label shall be clearly associated with the icon without obscuring the visual representation.

b. Consistency - Visual features, meanings, and specific uses of icons shall be consistent within and among applications.

- c. Feedback - Selecting an icon shall be acknowledged by highlighting the icon in such a way that the icon is not visually obscured. The icon shall remain highlighted during the time that it is selected.

9.6.3.1.7.4 Design Requirements for Actions in the Direct Manipulation Interface

- a. Movement and Selection - Users shall be able to move the pointing cursor to and select icons by the use of any available cursor control device (e.g., X-Y controllers and arrow keys).
- b. Opening - A user shall be able to "open" a selected icon by a single unique action.
- c. Initiating a Process - Users shall be able to initiate the process related to an icon (e.g., opening a file or launching an application) in multiple ways: Opening the selected icon; connecting an object icon to an action icon; or selecting an icon and entering a command, e.g., via the command language, command keystrokes, or menu.

9.6.3.1.7.5 Interactions with Windows

9.6.3.1.7.5.1 Design Considerations for Interactions with Windows - N/A

9.6.3.1.7.5.2 Design Requirements for Interactions with Windows

- a. Opening and Closing a Window - Users shall be able to open or close a window by direct physical action on the window.
- b. "Popping" Windows - In a layered windowing environment, users shall be able to move a window in a stack to the prominent position in the stack so that its contents are visible (known as "popping" the window to the front).

9.6.3.1.8 Data Forms/Form Filling

9.6.3.1.8.1 Design Considerations for Data Forms/Form Filling - N/A

9.6.3.1.8.2 Design Requirements for Data Forms/Form Filling

- a. Use - The primary uses of data forms shall be for data entry and computer command tasks in which information needed by the user is displayed and the user has to complete a form.
- b. Grouping - Displayed forms shall be arranged such that related items are grouped together.
- c. Format and Content Consistency - If paper forms and computer-displayed forms are used in concert in a data entry task, the format and content of the two types of forms shall be compatible, within the constraints of the task and the differences in information format.
- d. Distinctiveness of Fields - Fields or groups of fields shall be separated by lines or other delineation cues. Required fields shall be distinguished from optional fields.

e. Field Labels - Field labels shall be distinctively presented such that they can be distinguished from both data entry fields and data entered by the user. Labels for data entry fields shall incorporate additional cueing of data format where the entry is made up of multiple inputs [e.g., TIME (HH/MM/SS):(_/_/_)].

f. Cursor Placement - When the form is displayed, a displayed cursor shall be positioned by the system at the first data entry field to which the user has to provide input. The system shall advance the cursor to the next data field when the user has completed entry of the current field. The user shall also have the ability to move the cursor to the next field, to the previous field, or, independently, to any field on the form.

g. Actions for Movement and Completion - Distinctly different actions shall be used for:

1. Movement of the cursor forward to the next field.
2. Movement backward to a previous field.
3. Placing the cursor in a non-contiguous field.
4. Indicating that the input to the form is completed.

h. Entry Length Indication - The maximum acceptable length for variable length fields shall be indicated on that field. However, when the item length is variable, the user shall not have to remove unused underscores.

i. Overwriting - When data entry by overwriting a set of characters in a field is used, clear designation of overwritten characters (e.g., by reverse video) shall be provided.

j. Dimensional Units - When a consistent dimensional unit is used in a given entry field, the dimensional unit shall be provided and displayed by the system.

k. User Omissions - When required data entries have not been input, the omission shall be indicated to the user, and either immediate or delayed input of the missing items shall be allowed. For delayed entry, the user shall be required to indicate to the system (e.g., by entering a special symbol in the field) that the missing item is delayed, not overlooked.

l. Non-Entry Areas - Non-entry (protected) areas of the display shall be designated. In the absence of authorization of the user, those areas shall be made inaccessible.

m. Prevent Entry of Inappropriate Characters - An attempt to enter an inappropriate character into a field (e.g., entering an alphabetic character into a field reserved for entry of numeric characters) shall result in feedback from the system (e.g., an auditory signal and/or an error message).

9.6.3.1.8.3 Design Requirements for Default Values for Data Forms

a. Default Values - Default values shall be used to reduce user workload. Currently defined default values shall be displayed automatically in their appropriate data fields with the display of a form.

b. Default Modification - The user shall have the capability of changing default values and having those modifications retained by the system beyond that user interaction or session (i.e., until changed by another specific user action).

c. Default Substitution - The user shall be able to replace any default value during a given transaction without changing the default definition.

d. User Confirmation - If required, user acceptance of stored data or defaults shall be possible by a single confirming keystroke.

9.6.3.1.9 Question and Answer

9.6.3.1.9.1 Design Considerations for Question and Answer - N/A

9.6.3.1.9.2 Design Requirements for Question and Answer

a. Use - The uses for question and answer dialogues shall include:

1. Highly constrained tasks in which each step of the task sequence has few choices available.
2. Routine data or command entry tasks in which the user needs explicit prompting.

b. Structure:

1. The system shall provide the user with a specific request for information. A question mark shall be the delimiter of the question from the system.
2. The system shall provide the user with contextual information (e.g., units of measurement used in the answer) required for answering the question.
3. The area in which the user can enter the answer shall be provided following the question as closely as possible.
4. The system shall accept as much information as is provided by the user. If the input by the user is to be severely limited, a data form shall be used.
5. The system shall display related questions (and their associated answers) simultaneously. Unrelated questions (and their associated answers) shall be displayed separately.

9.6.3.1.10 User-definable Macros - N/A

9.6.3.2 Design Requirements for Movement Within User Interfaces

a. Users shall be able to move the locus of their input or attention within a display by means of a pointing cursor. A placeholder cursor shall be available for location of placement in a display used for input of alphanumeric characters.

- b. Users shall be able to move displayed information from the same data file by scrolling (i.e., the continuous vertical or horizontal movement of displayed information).
- c. Users shall be able to locate and move to specific information in a data file.

9.6.3.2.1 Design Requirements for Position Designation (Cursor)

- a. Control - Systems employing cursors shall provide cursor control capability consistent with user speed and accuracy requirements.
- b. Locating - All cursors shall be distinctive against all backgrounds and shall be easy to locate at any position on a display.
- c. Tracking - The cursor shall be easy for the user to track as it is moved through the display.
- d. Distraction - The cursor shall not distract or impair the user during the search of the display for information unrelated to the cursor.
- e. Data Entry - An "enter" action for data items shall result in the entry of all appropriate items (e.g., all data input to a data form or all text written in a text file) regardless of the placement of the cursor. The user shall not be required to move the cursor to any arbitrary position on the display (e.g., the top left or bottom right of the display).
- f. Home Position - The home position for the cursor shall be consistent across similar types of displays.
- g. Unique Shape - The shapes used for cursors shall be unique with respect to all other display structures. Cursors of different shapes shall be used for different purposes; the relation between a cursor shape and function shall be consistent across applications.
- h. Types of Cursor - Users shall have access to two functionally different types of cursors - a pointing cursor and a placeholder cursor.

9.6.3.2.1.1 Design Requirements for Pointing Cursor

- a. Display Priority - The pointing cursor shall be available to the user at all times. The pointing cursor shall obscure other characters unless this would interfere with user performance.
- b. Visual Characteristics:
 - 1. The pointing cursor shall not blink.
 - 2. The pointing cursor shall maintain its size and image quality across all screen and display locations.
 - 3. To the greatest degree possible, the pointing cursor shall be completely graphic and shall not contain a label.

c. Gross Movement:

1. The movement of the pointing cursor shall be systematically related to the movement of the cursor control device (e.g., a trackball, a joystick, a mouse, or cursor control keys).
 2. The pointing cursor shall not move in the absence of input from the user.
 3. The movement of the pointing cursor shall appear to be smooth and continuous with smooth and continuous movement of the cursor control device.
- d. Fine Positioning - When fine positioning accuracy is required, the displayed cursor shall include an appropriate point designation feature (e.g., crosshairs).

9.6.3.2.1.2 Design Requirements for Placeholder Cursor

- a. Non-Interference - The placeholder cursor shall not interfere with the reading of the character that it marks.
- b. Number of Placeholder Cursors - There shall be one and only one placeholder cursor in each window in which a user is entering alphanumeric characters.
- c. Visual Characteristics:
 1. The placeholder cursor shall assume the height or width of the alphanumeric characters adjacent to it.
 2. If the placeholder cursor blinks, the default blink rate shall be 3 Hz. A user-selectable blink rate shall be within the range of 3 to 5 Hz.

9.6.3.2.2 Design Requirements for Scrolling

- a. Method of Scrolling - Users shall be able to scroll by only one method within an application - either by "moving text" (i.e., the information in the display appears to move over a fixed display window) or by "panning" (i.e., a window appears to move over a fixed display of information). Panning shall be the preferred method.
- b. Scroll Rate - The scroll rate shall allow the user to scroll in an increment of a line and shall provide the appearance of a smooth flow of text.
- c. Direction of Scrolling - The direction that a user may be scrolling shall be evident before the user begins the scroll action (e.g., arrows might point in the direction that corresponds to the direction that scrolling will occur).
- d. Numbering - Items continued on the next page (scrolled to) shall be numbered relative to the last item on the previous page.

9.6.3.2.3 Design Requirements for Paging

- a. User Control - Users shall have control over paging by use of any of several methods (e.g., dedicated paging function keys and a display-based paging icon).

- b. **Paging Increments** - Users shall be able to move in increments of one or multiple pages.
- c. **Page Numbering** - Each page of a multiple page display shall be numbered to identify the currently displayed page and the total number of pages.
- d. **Direction of Paging** - The direction that a user may page shall be evident before the user begins to page (e.g., separate, labeled function keys might be used for paging forward and paging backward).

9.6.3.2.4 Design Requirements for Searching

- a. **Objects of Search** - Users shall be able to search for and move to :
 - 1. A specific line number.
 - 2. A literal string of alphanumeric characters.
- b. **Multiple Occurrences** - Users shall be able to find multiple occurrences of a literal string.

9.6.3.2.5 Hypertext

9.6.3.2.5.1 Design Considerations for Hypertext - N/A

9.6.3.2.5.2 Design Requirements for Hypertext

- a. **Restricted Access to Authoring** - Users shall only have access to authoring tools (i.e., tools that allow users to create, modify, or delete the representation of information or links between information) if they need to have the power of those tools. Users that only need to browse (i.e., search through a database to obtain information contained in the nodes by following links between nodes), shall not have access to authoring tools.
- b. **Browsing Tools** - Browsing tools shall generally use a question and answer dialogue.

9.6.3.3 Design Requirements for Manipulating Data - N/A

9.6.3.3.1 Editing

9.6.3.3.1.1 Design Considerations for Editing - N/A

9.6.3.3.1.2 Design Requirements for Editing

- a. **Use** - Users shall be able to edit only selected data files (e.g., files that they create and files specifically designated as read/write). Certain files shall be uneditable by the user. Editable files shall be clearly distinguishable from noneditable files.
- b. **Methods** - For all editable files, the user shall be able to edit text, tables, graphics, and any other data by means of any of several methods (e.g., command language commands, command keystrokes, and menus).

c. Consistency of Procedures - All editing procedures shall be consistent in dialogue structure, independent of the type of information being edited.

d. Modifying Physical Features:

1. The user shall have the ability to change the physical characteristics of text (e.g., the font type and size, italics, underlining, boldness, and capitalization).
2. The user shall have the ability to set and modify the tab position for user-modifiable text files.
3. The user shall be able to set and modify the margins for user-modifiable text files.

e. Insert Mode vs. Overstrike Mode - By default, the text editor shall operate in insert mode. Text shall be inserted moving to the right. However, the user shall be able to select text to be overstricken.

f. Selecting Data:

1. Users shall be able to select any editable data in any type of displayed data file (including text, tabular, or graphical) for specific editing functions (e.g., cutting, deletion, copying) with no more than two actions.
2. The selected data shall be visually distinct from non-selected data.
3. Users shall be able to remove selected data from the selected state with a single action.

g. Cutting Data:

1. Users shall be able to remove any editable data from a displayed data file by means of a "Cut" capability.
2. After the data are removed, the text or tabular display shall be reconstituted without a gap where the data were cut. Graphical displays shall be reconstituted with a gap where the graphical data were removed.
3. Users shall be able to place data that was most recently cut at a restricted location in any data file. Certain locations may be restricted from insertion of (or copied) data (e.g., menus or the system-originated parts of data forms).

h. Copying Data - Users shall be able to copy any editable data and replicate it at any unrestricted location in any data file.

l. Deleting Data - Users shall be able to delete previously-selected data by simple actions different from other editing functions (e.g., a dedicated "delete" command or function key).

1. Deletion of data shall be reversible for a limited period.
2. Deletion of critical data shall be protected by use of an "arm-fire" sequence, in which the user has to acknowledge that the system should delete the data.

9.6.3.3.2 Saving

9.6.3.3.2.1 Design Considerations for Saving - N/A

9.6.3.3.2.2 Design Requirements for Saving

a. Saving Data - The user shall have the ability to save data entered into an editable data file:

1. While continuing to interact with that file .
2. While simultaneously exiting from that file. Two different simple actions shall be used for these two different types of saving data.

b. Exiting a File - The user shall be able to exit a data file at any time without saving the changes to the file.

9.6.3.4 Design Considerations for User Guidance - N/A

9.6.3.4.1 Design Requirements for Consistent Terminology

Consistent Terminology - On-line documentation, on-line documentation, and help instructions shall use consistent terminology.

9.6.3.4.2 User Feedback

9.6.3.4.2.1 Design Considerations for User Feedback

9.6.3.4.2.2 Design Requirements for User Feedback

- a. Use - Clear and concise feedback shall be provided to users as necessary to provide status information throughout the interaction.
- b. Function Status - Feedback shall indicate actual function status.
- c. Standby - If a system process (or processes) is time-consuming and causes the screen and input devices to be locked out, a progress message shall be displayed and updated, if possible, advising the user of the time remaining for the task or of the percentage of the task completed.

d. **Process Outcome** - When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action.

e. **Input Confirmation** - Confirmation of user input shall occur without removing the data display.

f. **Highlighted Option Selection** - Highlighting of data, a message, a menu item, an icon, or other display structure shall be used as feedback by the system to acknowledge that the user has selected the item.

g. **User Input Rejection** - If the system rejects a user's input, feedback shall be provided to indicate :

1. The reason for rejection.
2. The required corrective action.
3. Where appropriate, the location of the problem.

9.6.3.4.3 System Status Messages

9.6.3.4.3.1 Design Considerations for System Status Messages - N/A

9.6.3.4.3.2 Design Requirements for System Status Messages

a. **Operational Mode** - The system shall inform the user of the current operational mode when the mode might affect the user's actions.

b. **System Changes** - The system shall inform users about system design or system operation changes only in those aspects that may affect the user's interaction with the system.

c. **Characteristics of Status Messages:**

1. Status messages shall be provided to the user in a consistent location on the display.
2. The message shall contain only the information needed by the user, and conveyed to the user in a form such that additional resources are not required to interpret the message, e.g.:
 - a) A description of the system state.
 - b) Directives for user action.
 - c) The consequences, if any, of failing to follow the directives.
3. If the user will not be able to look at a display, the message shall be presented by means of a voice production system and shall be repeatable.

4. If the user needs to be alerted that a status message is being displayed, status messages shall be accompanied by a consistent auditory signal. The auditory signal shall be redundant with the linguistic message.

9.6.3.4.4 Design Requirements for Error Handling

- a. Error Correction - The system shall provide users with a simple and easy capability to correct errors in input. Users shall be able to correct individual errors in a command string, sequence of commands, or data file by replacing only the erroneous input without having to re-enter correct input.
- b. Early Detection - A capability shall be provided to facilitate detection and correction of errors before they are entered into the system. In order to avoid disrupting the user, error checking shall occur at the earliest logical break in the user's command or data input (e.g., at the end of a data field or the end of a command).
- c. Timing of Feedback - If a user makes an incorrect command or data entry, the system shall detect the error and notify the user within two seconds from command or data entry.
- d. Internal Software Checks - User errors shall be minimized by the use of internal software checks of user entries for the validity of the item, the sequence of entry, completeness of the entry, and the range of the value.
- e. Error Message Content:
 1. Error messages shall be informative, brief and conveyed to the user in a form such that additional resources are not required to interpret the message.
 2. The error message shall be self-contained: The user shall not have to refer to external documents in order to interpret the error message.
 3. The error message shall be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user's behavior.
 4. To the greatest degree possible, the error message shall reflect the user's need for information and concept of the system, not those of the person who develops the message.
 5. Error messages shall be appropriate to the user's level of training and shall be as specific as possible to the user's particular application.
 6. Error messages shall explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition.
- f. Error Recovery and Process Change - The user shall be able to stop a process at any point in a sequence as a result of an indicated error. The user shall be able to return easily to any step in a multi-step process in order to nullify an error or to effect a desired change.

g. **Correction Entry and Confirmation** - When the user enters correction of an error, such corrections shall be implemented only by an explicit action by the user (e.g., actuation of an "Enter" key). All error correction by the user shall be acknowledged by the system, either by indicating that a correct entry has been made or by another error message if an incorrect entry has been made.

h. **Spelling Errors:**

1. Spelling and other common errors shall not produce valid system commands or initiate transactions different from those intended.

2. When possible, the system shall recognize, but not execute, common misspellings of commands. Computer-corrected commands, values, and spellings shall be displayed and highlighted for user confirmation prior to execution.

i. **Errors in Stacked Commands:**

1. To prompt for corrections of an error in stacked commands, the system shall display the stacked sequence with the error highlighted.

2. Where possible, a procedure shall be provided to correct the error and salvage the stack.

j. **Location of Error Messages** - Error messages shall be placed on the display close to the point of the error and/or in a designated, consistent area of the display.

9.6.3.4.5 Prompts

9.6.3.4.5.1 Design Considerations for Prompts - N/A

9.6.3.4.5.2 Design Requirements for Prompts

a. **Use** - Where appropriate, prompts and help instructions shall be used to explain commands, error messages, system capabilities, display formats, procedures, and steps in a sequence.

b. **Standard Display** - The location of prompts for data or commands shall be at the location of the desired input whenever possible. When the prompt cannot be placed at the location of the input, it shall be located in a standard message area.

c. **Prompt Language:**

1. Prompts shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.

2. Prompts shall be conveyed to the user in a form such that additional resources are not required to interpret the message. They shall not require reference to coding schemes, external documentation, or conventions which may be unfamiliar to occasional users.

9.6.3.4.6 On-Line Instruction**9.6.3.4.6.1 Design Considerations for On-Line Instruction - N/A****9.6.3.4.6.2 Design Requirements for On-Line Instruction**

Access to On-Line Documentation - For instruction, users shall have access to on-line documentation and descriptions of procedures.

9.6.3.4.7 On-Line Help**9.6.3.4.7.1 Design Considerations for On-Line Help - N/A****9.6.3.4.7.2 Design Requirements for On-Line Help**

a. Access to Help at Any Point in a Transaction - Users shall be able to access the Help function at any point in their interaction with the system. Access of help shall be by any of several methods, including:

1. Help provided automatically by the system when users make repeated frequent errors.
2. Input of a command language request for help.
3. Actuation of a "help" function key.
4. Selection of a help option in a menu.

b. System Response to Help Request - A help request from the user shall elicit a task specific and context sensitive response from the system.

c. Levels of Help - The Help function shall provide information at a level of detail that matches the needs of the user. The user shall first receive summary information about the requested topic, then can request for additional detailed information in a specific subtopic or subtopics.

d. Definitions Available - A dictionary of abbreviations, acronyms, and codes shall be available through the Help function, where feasible. Definitions of allowable options and ranges of values shall be displayed at the user's request where feasible.

e. Help about User Dialogues - At the user's request, the Help function shall provide the user with basic information about the semantics and syntax of any available user dialogue. Basic information shall include a structured listing containing each command, the associated keystroke commands and menu options, and the uses or consequences of the command.

f. Language of Help Messages:

1. Help messages shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.



2. Help messages shall be conveyed to the user in a form such that additional resources are not required to interpret the message.
3. Help messages shall not require reference to external documentation.

9.6.3.5 Design Requirements for Sequence Control

a. Hierarchical Process:

1. When hierarchical levels are used to control a process or sequence, the number of levels in depth in the hierarchy shall be minimized.
2. Display and input formats shall be similar within levels, and the system shall indicate the current positions within the sequence at all times.
3. Where it is appropriate for an experienced user to skip levels in a hierarchy, this capability shall be built in.

b. Interrupt:

1. User interrupts, processing aborts, and processing resumptions shall be allowed by the system. These actions shall not be modified by stored data.
2. The users shall be able to leave the system and store their work so that, on reentry at a later date, they can resume where they left off.

9.6.4 User Input

9.6.4.1 Design Considerations for User Input - N/A

9.6.4.2 Design Requirements for User Input

a. Consistent Consequences of User Input - The consequences of any user input shall be consistent:

1. For any individual user across time .
2. From user to user.

b. Relation of Input to Consequence - The consequences of the user's input shall be both logically and temporally linked to the input action so that the user can learn to predict what will happen following the input action.

c. Input via a Variety of Devices - System design shall not impose on the user the use of a specific input device when other devices are available and appropriate. However, users shall not be required to switch among multiple devices to perform the same function within a task.

d. **Computer Failure** - In the event of computer failure, the program shall allow for orderly shutdown and establishment of a check-point so restoration can be accomplished without significant loss of computing performed to date.

9.6.4.3 Design Requirements for Data Entry Design

a. **Learning** - The requirement to learn mnemonics, codes, special or long sequences, or special instruction shall be minimized.

b. **Abbreviations, Mnemonics, Codes, and Acronyms** - When abbreviations, mnemonics, codes, or acronyms are used to shorten data entry, they shall be distinctive and have a relationship or association to normal language or specific job related terminology.

c. **Length of Data Entries** - The length of individual data items that are part of a required data input shall not be longer than is practicable, (e.g., difficult to remember while typing or tedious to edit).

d. **Data Entry Pace** - Data entry shall be paced by the user, depending on the user's application, criticality of the operation, and attention span, rather than by the system.

e. **System Acknowledgment of Data Entry** - The system shall provide a positive feedback to the user indicating the acceptance or rejection of a data entry and shall indicate to the user processing delays of more than 15 seconds.

f. **Explicit Completion Action** - Data entry shall require an explicit completion action, such as the depression of an ENTRY key after a string input.

g. **Validation** - Data entries shall be validated by the system for correct format, legal value, or range of values. Where data is entered in sets with the same format and range of values, the entire data set shall be validated upon its completion.

h. **Input Units** - Data shall be entered in units which are familiar to the user.

i. **Software-Available Data** - The user shall not be required to enter data already available to the software.

j. **File Names** - Names of files shall be distinctive and descriptive of the contents of the files to aid in locating files and deterring accidental selection or deletion of files which have similar names.

k. **Originator Identification** - For reference, the system shall automatically associate the originator of a data file, text file, or message with the file's name.

9.6.4.4 Design Requirements for Interactive Control

a. **Simplicity** - The relationship between data entry and displays shall be straightforward and explicit. Data entry actions shall be simple and direct.

b. **Accidental Actuation** - Provision shall be made to prevent accidental actuation of potentially destructive control actions, including the possibility of accidental erasure or memory dump.

- c. Compatibility with User Skill, User Tasks - Controls for data entry shall accommodate the lowest anticipated user skill level.
- d. Availability of Information - Information necessary to select or enter a specific control action shall be available to the user when selection of that control action is appropriate.
- e. Minimized Keying - The amount of keying required shall be minimized by using numbered lists and abbreviations.
- f. Physical Characteristics of Selectable Items - Selectable items or regions shall not be so large that they waste screen space or may not be perceived as selectable.
- g. Multitasking/Multimonitor Considerations - In a multitasking environment with multiple monitors, controllers, or cursors, the location of the active cursor shall be apparent to the user. If there are two pointing cursors -- one on each of two monitors -- the active cursor shall be apparent to the user. If there is a single cursor that moves between two monitors, its path shall be continuously trackable.
- h. X and Y Outputs - The controller, with the exception of arrow keys or other discrete step keys, shall be able to produce any combination of x and y output values.
- i. X-Y-Z Control Outputs - Any controller shall be able to produce any combination of x, y, and z output values. Output in each of the three dimensions shall be discriminable from each other.

10.0 ACTIVITY CENTERS

10.1 INTRODUCTION - N/A

10.2 PERSONAL HYGIENE

10.2.1 Introduction - N/A

10.2.2 Personal Hygiene Design Considerations - N/A

10.2.3 Personal Hygiene Design Requirements

10.3 BODY WASTE MANAGEMENT FACILITIES

10.3.1 Introduction - N/A

10.3.2 Body Waste Management Facilities Design Considerations - N/A

10.3.3 Body Waste Management Facilities Design Requirements

10.3.3.1 Defecation and Urination Facilities Design Requirements - N/A

10.3.3.2 Facilities for Other Waste Products Design Requirements - N/A

10.3.3.3 Body Waste Management Accommodations Design Requirements

The following are requirements for the design of crew waste management.

a. Fecal Collection - Fecal collection capabilities shall meet the following requirements:

1. The equipment shall provide crew interfaces to accommodate the collection of fecal solids, liquids, gases, particulates, and associated consumable material (e.g., wipes).

2. Capacity - The fecal collection equipment shall have the following capacity:

a) The average per person per 24 hour day amount of fecal matter which the fecal collection devices shall accommodate shall be 142 gm (5.0 oz) by weight and 142 ml (8.5 in³) by volume.

b) The capability to accommodate a maximum of 1000 ml (61 in³) of diarrhea discharge shall be provided.

c) The fecal collector shall accommodate a maximum BOLUS length of 330 mm (13 in).

d) Quantities in excess of these amounts shall not result in an unresolvable condition.

3. The devices shall capture, isolate, stabilize, and store all wastes and wipes generated during defecation.

b. Urine Collection - Urine collection devices shall meet the following requirements.

1. The devices shall provide crew interfaces to accommodate liquid capture and splash control.

2. Capacity - The urine collection system shall have the following capacity:

a) The urine collection devices shall accommodate a maximum urine output volume of 4000 ml (244 in³) per person per day

b) The urine collection system shall be designed to accommodate urinary discharge up to 800 ml (49 in³) in a single micturition at a delivery rate of 50 ml/sec (3 in³/sec).

c) Urine volumes in excess of these amounts shall not result in an unrecoverable condition.

3. The devices shall capture, isolate, stabilize, and store all wastes and wipes generated during urination.

c. Other Waste Product Accommodations Readily accessible waste management provisions shall be able to collect and contain vomitus and menses.

d. Sanitation - The defecation and urination accommodations shall meet the following sanitation requirements:

1. The devices shall prevent cross contamination among the crewmembers.

2. The accommodations shall not contaminate other areas of the Assured Crew Return Vehicle.

e. Privacy - Where practical visual privacy for urination and defecation shall be considered.

f. Capacity - Sufficient urination and defecation accommodations and capacity shall be provided to allow use by the crew within mission time and schedule constraints.

g. Anatomical Accommodation Urination and defecation devices shall be provided to accommodate the physiological differences of male and female crewmembers and the anatomical size range of the crew.

h. Handling of Feces and Urine - If a crewmember is required to handle urine or feces samples for transfer to another area, the following requirements apply:

1. Crewmembers shall be protected from direct contact with waste material.

2. Waste material odors shall be controlled.

3. Methods shall be provided to prevent escape of waste material into the environment.

10.4 CREW QUARTERS - N/A

10.5 GALLEY AND WARDROOM - N/A

10.6 MEETING FACILITY - N/A

10.7 RECREATION FACILITY - N/A

10.8 MICROGRAVITY COUNTERMEASURE FACILITY - N/A

10.9 ASSURED CREW RETURN VEHICLE (ACRV) MEDICAL CAPABILITY - N/A

10.10 LAUNDRY FACILITY - N/A

10.11 TRASH MANAGEMENT FACILITY

10.11.1 Introduction - N/A

10.11.2 Trash Management Facility Design Considerations - N/A

10.11.3 Trash Management Facility Design Requirements

A trash receptacle shall be provided.

10.12 STOWAGE FACILITY

10.12.1 Introduction - N/A

10.12.2 Stowage Facility Design Considerations - N/A

10.12.3 Stowage Facility Design Requirements

The following are design requirements for the ACRV stowage facilities:

a. Location - The following are requirements for the location of stowage areas:

1. Proximity - Items shall be stored as close as possible to their point of use.
2. Safety - Hazardous items shall be stored away from heat or ignition sources and away from crew congregation areas.
3. Interference - Stowage facilities shall not interfere with normal or emergency crew operations.

b. Accessibility:

1. Stored items shall be accessible by the defined size range of the ACRV crew.
2. Removal of a stored item shall not require removal of another, unrelated item.

c. Labeling and Coding - Stowage locations and items shall be coded to allow for location, replacement, or inventory of items. The coding system shall allow modification.

d. Hand Operation - Stowage retainers shall be designed to be operated by hand; no tools shall be required.

e. Commonality - Latching devices, containers, and container covers shall have design commonality to the maximum extent practical throughout all ACRV stowage facilities with the Space Station Freedom (SSF).

f. Inventory Management - The stowage facility shall be compatible with the SSF inventory management system.

g. Retention Devices - Stowage items shall be secured within the container such that the item remains in the container/enclosure when the container is opened. Removal of retention devices shall not release other items which are not required.

11.0 HARDWARE AND EQUIPMENT

11.1 INTRODUCTION - N/A

11.2 TOOLS

11.2.1 Introduction - N/A

11.2.2 Tool Design Considerations - N/A

11.2.3 Tool Design Requirements

11.2.3.1 Hand and Tool Integration Design Requirements - N/A

11.2.3.2 Tool Commonality Design Requirements

ACRV tools shall be common with Space Station Tools for IVA and EVA maintenance.

11.2.3.3 Tool Tethering/Retention Design Requirements - N/A

11.2.3.4 Tool Stowage Design Requirements - N/A

11.2.3.5 Tool Labeling and Identification Design Requirements - N/A

11.2.3.6 Tool Access Design Requirements

The following tool access volume and operational constraints requirements are applicable to both IVA and EVA hardware design (refer to Figure 11.2.3.6-1 for IVA requirements and Paragraph 14.6.2.3 for EVA requirements):

- a. Tool Head Clearance - When only tool access is required, a 2.5 cm (1 in.) clearance shall be provided around the fastener or drive stud for insertion, actuation, and removal of the drive end of the tool.
- b. Tool Handle Clearance - A minimum of 7.6 cm (3 in.) shall be provided for clearance between a tool handle engaged on a fastener or drive stud and the nearest piece of hardware. The tool handle should be able to maintain this clearance through a full 180 deg. swept envelope.
- c. Tool Head-to-Fastener Engagement Height - The tool socket/fastener head engagement height shall be a minimum of 0.7 cm (0.3 in.).
- d. Tool Handle Offset - The maximum tool offset between the tool handle and the tool head shall be 35.5 cm (14 in.).
- e. Access for Tools - Minimum tool access clearance for hand tool actuation is given in Figure 11.2.3.6-2.

11.3 DRAWERS AND RACKS

11.3.1 Introduction - N/A

11.3.2 Drawer and Rack Design Considerations - N/A

11.3.3 Drawer and Rack Design Requirements

11.3.3.1 Drawer and Rack Interfacing Requirements - N/A

11.3.3.2 Design Requirements Common to Both Stowage and Equipment Drawers

All stowage and equipment drawers shall be designed to provide the following features:

- a. Latches/Handles/Operating Mechanisms - All latches, handles, and operating mechanisms shall be designed to be easily latched/unlatched and opened/closed with one hand by the entire crewmember population without having to use any operating instructions.
- b. Latch/Unlatch Status - The design shall be such that it is obvious when the drawer is not fastened/locked when in the closed position.

11.3.3.3 Stowage Drawer Design Requirements

Stowage drawers shall be designed to meet the following requirements:

a. Restraint of Contents :

1. Drawer contents shall be restrained in such a way that the items shall not float free when the drawer is opened, or jam the drawer so it cannot be opened or closed.
2. Drawer contents shall be restrained in such a way that the contents can be removed/replaced without using a tool.

b. Arrangement in Housing/Cabinet - Drawers shall be arranged within their housing/cabinet such that the most frequently accessed drawers are in the most accessible locations.

c. Access to Contents - The contents of drawers shall be arranged such that the contents are visible and accessible when the drawer is in the open position.

d. Identification of Contents - In the stowed position, the contents of drawers shall be identified by labeling.

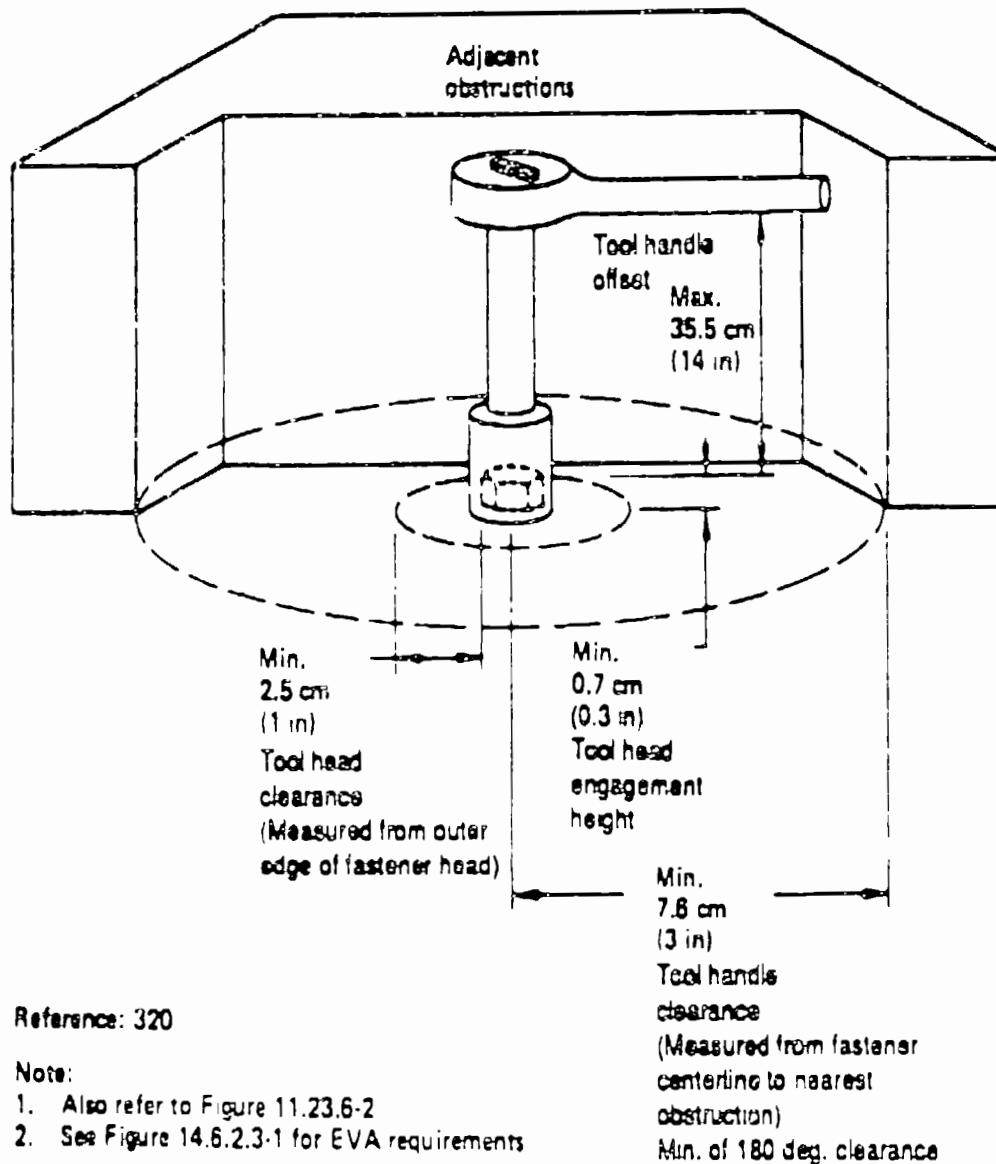


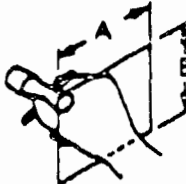

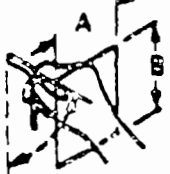


Figure 11.2.3.6-1 Tool Access Requirements (IVA)

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Opening dimensions	Task
 <p>A 117 mm (4.6 in) B 107 mm (4.2 in)</p>	Using common screwdriver with freedom to turn handle through 180°
 <p>A 133 mm (5.2 in) B 115 mm (4.5 in)</p>	Using pliers and similar tools
 <p>A 155 mm (6.1 in) B 135 mm (5.3 in)</p>	Using T-handle wrench with freedom to turn wrench through 180°
 <p>A 203 mm (8.0 in) B 135 mm (5.3 in)</p>	Using open-end wrench with freedom to turn wrench through 62°
 <p>A 122 mm (4.8 in) B 155 mm (6.1 in)</p>	Using Allen-type wrench with freedom to turn wrench through 62°

Reference: 1, Table 4.4-7

Notes:

1. Also refer to Figure 11.2.3.6-1 for other hand and arm access hole dimensions
2. Also refer to Figure 11.2.3.6-1

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Figure 11.2.3.6-2 Minimal Clearance for Tool-Operated Fasteners

11.3.3.4 Equipment Drawer Design Requirements

Equipment drawers shall be designed to meet the following requirements:

a. Utility Connections :

1. The utility connections shall be designed to be easily disconnected/connected when the drawer is in the fully opened position.
2. If the utility connection is via a flexible umbilical, sufficient cable length shall be provided such that the drawer can be fully opened without disconnecting the cables.

b. Equipment Layout on Rack :

1. Components shall be mounted in an orderly array on a two-dimensional surface, rather than stacked one on another (i.e., a lower layer shall not support an upper layer).
2. Items of the same or similar form, but having different functional properties, shall be mounted with a standard orientation throughout the unit, but shall be readily identifiable and distinguishable, and shall not be physically interchangeable.
3. Delicate items shall be located or guarded so that they will not be susceptible to damage while the unit is being handled or maintained.

11.4 CLOSURES AND COVERS**11.4.1 Introduction - N/A****11.4.2 Closures and Covers Design Considerations - N/A****11.4.3 Closures and Covers Design Requirements**

Equipment housings (e.g., electrical bays, cabinets, lockers, and consoles) shall be designed to provide closures and covers for inaccessible areas. The following requirements shall apply:

- a. Sealing - The inaccessible areas shall be sealed to prevent small items from drifting into them.
- b. Removal - Closures shall be quickly and easily removed to allow maintenance of equipment.
- c. Securing - It shall be obvious when a closure is not secured, even though it may be in place.
- d. Loads - Nonstructural closures should be capable of maintaining closure and of sustaining a crew-imposed minimum design load of 451 N (125 lbf) and a minimum ultimate load of 632 N (175 lbf).
- e. Instructions - If the method of opening a cover is not obvious from the construction of the cover itself, instructions (including applicable tool instructions) shall be permanently displayed on the outside of the cover.

- f. Clearance - Bulkheads, brackets, and other units shall not interfere with removal or opening of covers.
- g. Application - An access cover shall be provided whenever frequent maintenance operations would otherwise require removing the entire case or cover, or dismantling an item of equipment.
- h. Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position.
- i. Ventilation Screen Access - Where ventilation screens, holes, or grids are used, the ventilation surface shall be accessible for vacuuming in its installed position.

11.5 MOUNTING HARDWARE

11.5.1 Introduction - N/A

11.5.2 Mounting Hardware Design Considerations - N/A

11.5.3 Mounting Hardware Design Requirements

11.5.3.1 General Mounting Design Requirements

The following general requirements apply to mounting hardware:

- a. Equipment Mounting - Equipment items shall be designed so that they cannot be mounted improperly.
- b. Drawers and Hinged Panels - Subsystem components which are frequently pulled out of their installed position for checkout shall be mounted on equipment drawers or on hinged panels.
- c. Layout - Components shall be mounted so that a minimum amount of place-to-place hand movements will be required during operations.
- d. Covers or Panels - Removal of any replaceable item shall require opening or removing a minimum number of covers or panels.
- e. Installation/Removal Force - Hardware mounted into a capture-type receptacle that requires a push-pull action shall require a force less than 156N (35 lbf.) to install or remove.
- f. Rear Access - Equipment to which rear access is required shall be free to open or rotate to their full distance travel and remain in the "open" position without being supported by hand.
- g. Tools - Whenever possible, items shall be replaceable with a common hand tool.
- h. Direction of Removal - Replaceable items shall be removable along a straight or slightly curved line, rather than through an angle.

i. Visibility - All forward edges of the equipment item shall be visible to the restrained crewmember during alignment and attachment.

j. Spacing - Mounting bolts and fasteners shall be spaced far enough from other surfaces to allow personnel to manipulate them.

k. Number of Mounting Bolts - Use the minimum number of fasteners, consistent with stress and vibration requirements, so that the crewmember's workload is minimized.

l. Shims, Washers - Where shims or washers are permitted in an IVA application, the following rules shall be followed:

1. Shims shall be bound together in a shim assembly.
2. Shim assemblies shall be tethered or restrained at the location or point of use and identified as to location or point of use.
3. A similar requirement shall be observed for washers and other loose items which are auxiliary connector/fastener devices.

11.5.3.2 Alignment Devices Design Requirements

The following alignment methods for replaceable hardware shall be used:

a. Alignment Marks - If proper interface orientation is not obvious by virtue of external geometry or if adequate visibility cannot be provided for hardware that will be mounted on-orbit, the hardware design shall incorporate alignment marks and/or orientation arrows.

1. Alignment marks shall be applied to both mating parts and the marks shall align when the parts are in the operational position.
2. An alignment mark shall consist of a straight line of a width and length appropriate to the size of the item.
3. Alignment marks shall be clearly visible to a crewmember performing hardware removal/replacement.

b. Alignment Devices - Guide pins or their equivalent shall be provided to assist in alignment of hardware during mounting, particularly on modules that have integrated connectors.

c. Keying - All replaceable hardware shall be designed so that it will be physically impossible to install it in the wrong orientation.

d. Replaceable Hardware Identification - Replaceable hardware shall be identified with nomenclature that aids the crewmember in identifying the hardware name, alignment of the hardware, and the correct use of attaching parts.

11.6 HANDLES AND GRASP AREAS (FOR PORTABLE ITEMS)**11.6.1 Introduction - N/A****11.6.2 Handle and Grasp Area Design Considerations - N/A****11.6.3 Handle and Grasp Area Design Requirements****11.6.3.1 General Handle and Grasp Area Design Requirements**

The following general requirements shall be observed:

- a. Provide Handles - All removable or portable units shall be provided with handles or other suitable means for grasping, tethering, handling, and carrying.
- b. Exempt Items - Items less than 0.03 m³ (1 ft³) whose form factor (shape) permits them to be handled easily shall be exempt from the above requirement.
- c. Labeling of Nonhandling Areas - Built-in features that appear to be suitable for grasping/tethering/restraining and are not suitable must be labeled to indicate that these features are not suitable for these purposes.

11.6.3.2 Handle and Grasp Area Location Design Requirements

The following general location requirements of handles or grasp areas shall apply:

- a. Interference - Handles and grasp areas shall be located so that they do not interfere with equipment location or maintenance.
- b. Clearance - Clearances shall be provided between handles and obstructions consistent with anthropometric requirements.
- c. Tether Attachments - Handles and grasp areas shall be suitable as tether or bracket attachment positions.
- d. Location - The location of handles or grasp areas shall be such that they do not constitute passageway hindrances or safety hazards. If they must be located in passageways they shall be recessed and designed to minimize chance of crewmember injury or inadvertent contact.
- e. Location/Front Access - Handles and grasp areas shall be placed on the accessible surface of an item consistent with the removal direction.

11.6.3.3 Nonfixed Handles Design Requirements

Hinged, foldout, or attachable (i.e., nonfixed) handles shall comply with the following:

- a. Locked or Use Position - Nonfixed handles shall have a stop position for holding the handle perpendicular to the surface on which it is mounted.

b. One-Handed Operation - Nonfixed handles shall be capable of being placed in the use position by one hand and shall be capable of being removed or stowed with one hand.

c. Tactile or Visual Indicators - Attachable/removable handles shall incorporate tactile and/or visual indication of locked/unlocked status.

11.6.3.4 Handle Dimensions Design Requirements

IVA handles for movable or portable units shall be designed in accordance with the minimum applicable dimensions in Figure 11.6.3.4-1.

11.7 RESTRAINTS

11.7.1 Introduction - N/A

11.7.2 Personnel Restraints

11.7.2.1 Introduction - N/A

11.7.2.2 Personnel Restraints Design Considerations - N/A

11.7.2.3 Personnel Restraints Design Requirements

11.7.2.3.1 General Personnel Restraints Design Requirements - N/A

11.7.2.3.2 Foot Restraint Design Requirements - N/A

11.7.2.3.3 Body Restraint Design Requirements

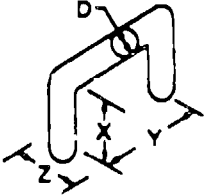
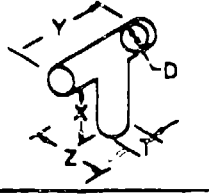
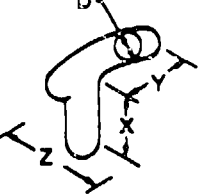
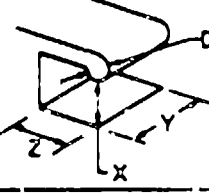
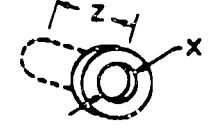
11.7.2.3.3.1 Body Restraint Donning/DoFFing Design Requirements - N/A

11.7.2.3.3.2 Body Restraint Loads Design Requirements

The following load requirements shall apply to seat belts, shoulder harnesses, and IVA tethers:

a. Seat Belts and Shoulder Harnesses - Seat belts and shoulder harnesses installed at stations designated as occupied during landing shall be designed so the occupant making proper use of the equipment will not suffer serious injury when the following impact forces acting separately are imposed on the crewmember. These requirements are given in Figure 5.3.3.3-1.

b. Body Harnesses - Body harnesses shall have lifting attach points (D-ring) which can be used in lifting or hoisting the crewmember during egress operations in a one-g environment. The body harness shall be designed to support the load of the crewmember while being lifted or hoisted. The body harness can be designed to be an integral part of the seat belt and shoulder harness restraint system or be designed as a separate harness to be worn in addition to the seat belt and shoulder harness restraint system.

Illustration	Type of handle	Dimensions in mm (in inches)		
		(Bare hand)		
		X	Y	Z
	Two-finger bar	32 (1-1/4)	65 (2-1/2)	75 (3)
	One-hand bar	48 (1-7/8)	111 (4-3/8)	75 (3)
	Two-hand bar	111 (4-1/8)	215 (8-1/2)	75 (3)
	T-bar	38 (1-1/2)	100 (4)	75 (3)
	J-bar	50 (2)	100 (4)	75 (3)
	Two-finger recess	32 (1-1/4)	65 (2-1/2)	75 (3)
	One-hand recess	50 (2)	110 (4-1/4)	80 (3-1/2)
	Finger-tip recess	19 (3/4)	—	13 (1/2)
	One-finger recess	32 (1-1/4)	—	50 (2)
Curvature of handle or edge (DOES NOT PRECLUDE USE OF OVAL HANDLES)	Weight of item	Minimum diameter		
	Up to 8.8 kg (up to 15 lbs)	D = 6 mm (1/4 in)	Grip point is best if force is applied around hand. Any angle of 20° or more	
	8.8 to 9.0 kg (15 to 20 lbs)	D = 13 mm (1/2 in)		
	9.0 to 18 kg (20 to 40 lbs)	D = 19 mm (3/4 in)		
	Over 18 kg (over 40 lbs)	D = 25 mm (1 in)		
	T-bar post	T = 13 mm (1/2 in)		

Reference: 2, Figure 48, page 197

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Figure 11.6.3.4-1 Minimum IVA Handle Dimensions for IVA Applications

c. Tether Attachments - IVA tether attachments shall be capable of sustaining a load of 756 N (170 lbf) along the longitudinal axis. They shall be designed so as to preclude any side loading.

d. Attach Points for Tether Attachment - IVA translation and mobility handhold tether attachment attach points shall be designed to a minimum ultimate load of 1113 N (250 lbf) in any direction.

11.7.2.3.3.3 Body Restraint Finish and Color Design Requirements

Markings, labeling, and colors shall be in accordance with Paragraph 9.5.

11.7.2.3.3.4 Body Restraint Dimensional Design Requirements

The following dimensional requirements shall apply to all seat belts, shoulder harnesses, and tethers:

a. Commonality - Seat belts, shoulder restraints, waist restraints, and tether attachments shall be uniform in size, shape, and method of operation within the limits of task performance and other design tradeoffs.

b. Size - Task requirements for which the attachment is designed shall dictate the actual size of the hooking and latch mechanism.

11.7.3 Equipment Restraints

11.7.3.1 Introduction - N/A

11.7.3.2 Equipment Restraint Design Considerations - N/A

11.7.3.3 Equipment Restraint Design Requirements

All IVA and EVA equipment restraints shall be designed to the following requirements:

a. Hand Operated :

1. Equipment restraints shall be designed such that tools are not required to attach or detach the restraint.

2. Equipment restraints shall be designed such that they can be attached/detached by either the left or right hand.

b. Blind Operation - The equipment restraints shall be designed such that they can be attached/detached without having to look at them.

c. Adjustability - Provide the capability to adjust the restraint to adapt to a wide range of sizes of the items to be restrained and to provide the user with the capability to restrain the item at a preferred location relative to the restraint attachment points. This does not preclude fixed-length tethers used for specific applications.

d. Positive Restraint - The restraint shall secure the item in such a way that the item will not come loose due to inadvertent touching, air currents, vehicle dynamic motions, or due to other predictable environmental conditions.

e. Cause No Damage - The equipment restraint shall be designed such that it cannot pinch, abrade, or cut the item to be restrained or the interfacing surfaces and adjacent hardware.

f. No Adhesive Residue - Adhesive equipment restraints shall not leave an adhesive residue on the item or on the spacecraft surface when the adhesive restraint is detached.

g. Tethers :

1. Common attachment method - All equipment tethers shall use a common attachment method.

2. Tether attachment points - All equipment items that require tethering shall have a standardized tether hook receptacle as an integral part of the item. This standardized receptacle shall also be provided on the interfacing surface to which the item is to be secured.

3. Tether lock status indication - The tether hook shall be designed in such a way that it will be easy to recognize when the hook is locked/unlocked in both day and night lighting conditions.

h. Loads :

1. Minimum load - The minimum design load shall be based on the expected crew-imposed and environmental loads to be applied to the item in the normal operating conditions.

2. Maximum load - The maximum design load shall be based on the resultant load imposed by a crewmember attempting to dislodge a restrained item that has become entrapped in adjacent hardware. The stress of this activity should not exceed the design load of the surface to which the restraint is attached or the design load of the entrapping hardware (i.e., the restraint should break before the item, attachment surface, or entrapping hardware breaks).

i. Color - Equipment restraints shall be of a standardized color to distinguish them from other types of loose equipment or items that will be restrained.

j. Commonality - Provide commonality of design for equipment restraints to the maximum extent possible.

k. Individual Restraints :

1. Individual restraints shall be designed to restrain one hardware item only.

2. Individual restraints shall be used when the restrained item is large in size, sensitive, or delicate or when attachments are difficult or complex in operation.

l. Group Restraints :

1. Group restraints shall be used to restrain like-sized items wherever possible.
 2. Group restraints shall provide a system that allows the removal of one item at a time.
- m. Throw-Away Restraints** - Any restraint device that is utilized during vehicle launch, and upon activation or usage removal is discarded, shall meet the following requirements:
1. Large throw-away restraints shall be designed to be torn apart or be of soft, crushable materials to accommodate the openings of onboard trash collection/disposal systems.
 2. The throw-away restraints shall be color coded as a throw-away item.
- n. Velcro** - When Velcro is used as a restraint, the item to be restrained will be equipped with hook-type Velcro and the restraining surface will be equipped with pile-type Velcro.

11.8 MOBILITY AIDS

11.8.1 Introduction - N/A

11.8.2 Personnel Mobility Aids

11.8.2.1 Handhold and Handrail Design Considerations - N/A

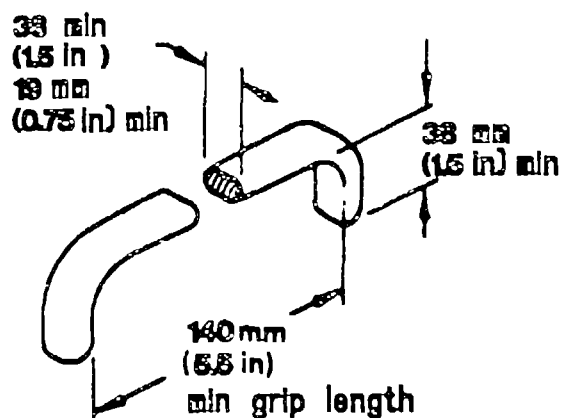
11.8.2.2 Handhold and Handrail Design Requirements

This section provides the design requirements for handholds and handrails. These requirements shall apply to both IVA and EVA applications except where EVA-unique requirements are specifically identified.

11.8.2.2.1 Handhold and Handrail Dimensions Design Requirements

All handholds and handrails shall adhere to the following cross-section design requirements:

- a. **Standardization** - Cross-sectional dimensions of handholds and handrails shall be standardized throughout the space module to provide a uniform interface for mounting items such as brackets and tether hooks.
- b. **Cross-Section Shape** - Handholds and handrails cross-section shape shall be designed such that the crewmember's hand or attached brackets will be stabilized (i.e., circular cross-section shall not be used).
- c. **IVA Handhold Minimum Dimensions** - All IVA handholds shall have a minimum of 14 cm (5.5 in.) grip length and a minimum of 3.8 cm (1.5 in.) clearance between the lower surface of the handgrip and the surface on which it is mounted. (Reference Figure 11.8.2.2.1-1.)



Reference: 1 Figure 4.1-5, page 4.1-2
With Updates

**Figure 11.8.2.2.1-2 IVA Handhold
Dimensions**

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11.8.2.2.2 Handhold and Handrail Coding Design Requirements

Handholds and handrail coding shall be such that the crew may locate them with ease:

- a. **Standard Color** - The color of all handholds/handrails shall be standardized within the space vehicle.
- b. **Contrast Ratio** - The color value shall have a contrast ratio of 3:1 or greater with the background.
- c. **Distinguishing Color** - The handhold/handrail shall be distinguishable from the surrounding area.

11.8.2.2.3 Handhold and Handrail Finish Design Requirements

Handhold and handrail texture shall be such that the crew may locate them by feel and grasp them with ease:

- a. **Identical Finish** - The finish of all handholds/handrails shall be identical to enhance identification.
- b. **Safety** - Handholds and handrails shall have a smooth surface with no burrs, sharp edges, or protrusions.
- c. **Durability** - The finish of all handholds and handrails shall be resistant to scratches, wear, flaking, and peeling.

11.8.2.2.4 Handhold and Handrail Design Loads Design Requirements

All fixed and portable IVA handholds and handrails shall be designed to a minimum ultimate load of 1113 N (250 lbf) applied in any direction without failure or damage that precludes full utilization by crewmembers.

11.8.2.2.5 Handhold and Handrail Temperature Design Requirements - N/A**11.8.2.2.6 Handhold and Handrail Mounting Design Requirements**

The following requirements shall apply to all handhold and handrail mounting:

- a. Stability - All fixed and portable handholds and handrails shall be designed so that when installed there is no instability (i.e., looseness, vibration, or slippage).
- b. Portable Handhold and Handrail Lock Status Indication - Portable handhold and handrails shall provide a positive indication of when they are in the locked position.
- c. Visibility and Accessibility - Handholds and handrails shall be mounted so that they are clearly visible and accessible.
- d. Handhold Removal - Fixed handholds shall be removable with common tools.
- e. Safety - Handrails and associated mounting provisions shall be designed so as to preclude snagging of body, clothing, and/or loose equipment (e.g., cables). Loose equipment shall not interfere with the operation of the equipment.

11.8.3 Equipment Mobility Aids**11.8.3.1 Equipment Mobility Aid Design Considerations - N/A****11.8.3.2 Equipment Mobility Aid Design Requirements**

The following equipment mobility and requirements are applicable to both IVA and EVA:

- a. Maximum Movable Equipment Size - Equipment size shall be limited to the dimensions and configuration of the smallest hatch or opening through which the equipment must pass.
- b. Access - Design shall provide adequate area around the mass for manipulation and visibility.
- c. Containers for Small Items - Containers shall be provided for simultaneous transfer of small equipment items.
 - 1. Single items shall be individually removable
 - 2. The container shall be easily attached to the crewmember and space module at the worksite.

d. Bump Protection - Bump protection shall be provided. Bump protectors shall be designed so they can be used as mobility aids.

11.9 FASTENERS

11.9.1 Introduction - N/A

11.9.2 Fastener Design Considerations - N/A

11.9.3 Fastener Design Requirements

This section provides the fastener design requirements. Paragraph 11.9.3.1 provides general fastener design requirements. Paragraph 11.9.3.2 provides requirements that are applicable to hand-actuated fasteners. Paragraph 11.9.3.3 provides requirements that pertain to tool-actuated fasteners. Paragraph 11.9.3.4 provides the design requirements that pertain to IVA fasteners.

11.9.3.1 General Fastener Design Requirements

This section provides the fastener design requirements that pertain to both IVA and EVA applications.

- a. Commonality - The number and diversity of fasteners shall be minimized commensurate with the structural requirements imposed by the physical environments.
- b. Easily Distinguishable - Where different types of fasteners must be used, they shall be such that they are readily distinguishable from each other.
- c. Hand-Actuated Fasteners Preferred - Hand-actuated fasteners shall be given preference over tool-actuated fasteners, provided that size, location, and structural constraints are met.
- d. Other Devices in Lieu of Fasteners - Optimum use shall be made of mechanical devices (e.g., hinges and tongue-and-slot catches) to minimize the number of fasteners.
- e. Captive Fasteners - All fastener components intended for crew interaction shall be captive. All replaceable fasteners shall be amenable to loose parts control and a means of fastener containment and/or restraint shall be incorporated in the fastener removal/replacement system.
- f. Accessibility :
 - 1. Location Near Corners - Fasteners shall be located far enough away from internal corners, wall edges, flanges, etc., that they can be manipulated with ease.
 - 2. Separation - Fasteners shall be located far enough apart so there is adequate hand or tool clearance.
 - 3. Location Near Adjacent Equipment - If a component is to be mounted near other pieces of equipment, fasteners shall be located away from the edges of the adjacent equipment, obstructions, or surfaces that will prevent the attachment of tools.

4. Direct Access - Locate fasteners so that they can be actuated without removing other parts or units first.
5. Access Holes - Covers or shields through which mounting fasteners must pass for attachment to the basic chassis of the unit shall have large enough holes for passage of the fastener without precise alignment (and tool/hand if tool/hand is required to replace).
- g. One Handed Actuation - All fasteners shall be designed to be actuated by one hand.
- h. Engagement Status Indication - Incorrect engagement of fasteners shall be apparent.
- i. Multiple Fasteners :
 1. Number of Fasteners - When several fasteners are required, the design shall use the minimum number of the largest size fasteners of identical type.
 2. Arrangement - When several fasteners are used on one item, they shall be arranged so that the unit can be assembled in only the correct manner.
- j. Safety - Fasteners shall be designed so as to preclude injury to the crewmember when the fastener is released.
- k. Labeling - Appropriate markings shall be placed on fasteners that can be actuated by either hand or tool.
- l. Replacement - All fasteners shall be designed for on-orbit replacement.

11.9.3.2 Hand-Actuated Fastener Design Requirements

In addition to the general fastener design requirements given in Paragraph 11.9.3.1, IVA and EVA hand-actuated fasteners shall be designed to the following requirements:

- a. One-Handed/Either-Hand Actuation - Hand-actuated fasteners shall be designed to be actuated by one hand and by either the left or right hand.
- b. Designed for Launch and On-Orbit - Fasteners shall be designed to meet the launch loads as well as on-orbit loads.
- c. Fastener Knobs - Fastener knobs shall be textured.
- d. Quick-Opening Fasteners - Quick-opening captive fasteners shall:
 1. Require a maximum of one complete turn to operate (quarter-turn fasteners are preferred).
 2. Require only one hand to operate.
 3. Be positive locking in open and closed position.

e. **Locking Threaded Fasteners** - Hand-actuated threaded fasteners shall have a locking feature that provides an audible, tactile, or visual feedback to the crewmember. Such locking features shall assure that threaded fasteners will not un-thread themselves without crew actuation.

f. **Pin Fasteners (IVA)** - Locking devices used in conjunction with pin fasteners shall be made accessible and easily visible.

g. **Over-Center Latches :**

1. **Non-self-latching** - Over-center latches shall include a provision to prevent undesired latch element realignment, interference, or reengagement.

2. **Latch lock** - Whenever possible, latch catches shall be spring loaded to lock on contact, rather than using a positive locking device. If positive locking is necessary, provide a latch loop and locking action.

3. **Latch handles** - If the latch has a handle, locate the latch release on, or near the handle so it can be operated with one hand.

h. **Safety Wire** - Safety wires shall not be used on fasteners.

11.9.3.3 Tool-Actuated Fastener Design Requirements

In addition to the general fastener design requirements given in Paragraph 11.9.3.1, IVA and EVA tool-actuated fasteners shall meet the following design requirements:

a. **Nonstandard Tools** - Fasteners requiring nonstandard tools shall not be used.

b. **High-Torque Fasteners (IVA Only)** - External hex or external double-hex fastener heads are preferred and they shall be provided on all machine screws, bolts, or other fasteners requiring more than 14 Nm (10 ft-lbs) of torque. Internal wrenching fasteners shall be Allen-head-type fasteners.

c. **Low-Torque Fasteners :**

1. Hex-type internal grip head, hex-type external grip head, or combination-head (hex or straight-slot internal grip and hex-type external grip head) fasteners shall be used where less than 14 Nm (10 ft-lb) of torque is required.

2. Internal-grip head fasteners shall be provided only where a straight or convex smooth surface is required.

3. No straight-slot or Phillips-type internal grip fasteners shall be used.

d. **Precision Torquing** - When possible, design equipment so that precise torque on fasteners is not required. Where precise torque or preload is required, use fasteners that incorporate torque-indicating features or that will mate with appropriate on-board torquing tools.

- e. **Torque Labeling** - When fastener torquing to specifications is required, an instructional label shall be provided in reasonable proximity to the fasteners.
- f. **Number of Turns** - When machine screws or bolts are required, the number of turns and the amount of torque shall be no more than necessary to provide the required strength.
- g. **Fastener Head Length (IVA Only)** - Fastener heads shall be as short as possible so they will not snag personnel clothing or equipment.
- h. **Left-Hand Threads** - Left-hand threads shall not be used unless system requirements demand them; then identify both the bolts and nuts clearly by use of markings, shape, color, etc.
- i. **Locking** - Threaded fasteners shall incorporate features that allow them to be locked so that they will not unthread without using a tool.
- j. **Hand Tool Operable** - All fasteners installed with power tools shall be removable with a hand-operated tool.

11.9.3.4 IVA Fastener Design Requirements

In addition to the fastener design requirements given in Paragraphs 11.9.3.1 through 11.9.3.3, all IVA fasteners shall meet the following requirements:

- a. **Fastener Lubrication** - IVA fasteners that require lubrication shall use an approved lubricant or plating material.
- b. **Cadmium Plating** - Cadmium-plated IVA fasteners shall not be used.
- c. **Wing-Head Fasteners** - Wing-head IVA fasteners shall fold down and be retained flush with surfaces so they will not snag personnel, clothing, or equipment.
- d. **Cotter Keys :**
 - 1. **Fit** - Keys and pins shall fit snugly without requiring being driven in or out using a tool.
 - 2. **Large heads** - Cotter keys shall have large heads for easy removal by hand.
 - 3. **Cotter keys shall not be used EVA.**
- e. **Access** - Minimal requirements for access and/or clearance areas for tool-actuated fasteners shall be as shown in Figures 11.2.3.6-1 and -2.
- f. **Tool-Actuated Fastener Head Types** - In addition to the general tool-actuated fastener design requirements given in Paragraph 11.9.3.3, the following IVA-specific tool-actuated fastener selection requirements shall apply:

(NOTE: Special mission or program requirements may create the need to use other types of fastener heads than those listed below.)

1. Fastener heads directly exposed to crew impact shall meet the requirements for burrs, edges, and sharp corners, or shall be provided with protective covers or they shall be flush with surface.

2. Fastener heads not directly exposed to crew impact within habitability and stowage areas shall be internal or external hex head.

g. Due to Potential toxicity/particulate contamination hazards associated with the use of anti-sieze and positive locking compounds, designers should avoid the need for the use of such chemicals, if at all possible.

11.10 CONNECTORS

11.10.1 Introduction - N/A

11.10.2 Connector Design Considerations - N/A

11.10.3 Connector Design Requirements

All types of IVA and EVA connectors shall meet the following general requirements:

a. One-Handed Operation - All connectors, whether operated by hand or tool, shall be designed so they can be mated/demated using one hand.

b. Accessibility - It shall be possible to mate/demate or replace individual connectors without having to remove or replace other connectors. Quick Disconnects (QDs) that are designed to be operated under pressure will not require pressure/flow indicators.

11.10.3.1 Fluid Connectors Design Requirements

All IVA and EVA liquid and gas connectors shall be designed to meet the following requirements:

a. Fluid Line Connectors - All brazed or welded gas and liquid lines shall be provided with convenient-to-use, permanently installed connectors that permit on-orbit maintenance.

b. Indication of Pressure Flow - All liquid and gas lines shall be provided with a positive indication of the gas pressure/fluid flow to verify that the line is passive before disconnection of connectors. Quick Disconnects (QDs) that are designed to be operated under pressure will not require pressure/flow indications.

c. Fluid Loss - Liquid and gas connectors shall be designed to minimize escape or loss of fluids, particularly any toxic materials, during connect or disconnect operations.

11.10.3.2 Electrical Connectors Design Requirements

All IVA and EVA electrical connectors shall comply with the following general requirements.

a. Ease of Disconnect - Electrical connector plugs shall require no more than one turn of disconnect or some other quick disconnect design shall be provided.

- b. Self-Locking - Electrical connector plugs shall provide a self-locking safety catch.
- c. Access - Electrical connectors and cable installations shall be designed with sufficient flexibility, length, and protection to permit disconnection and reconnection without damage to wiring or connectors.
- d. Arc Containment - Electrical connector plugs shall be designed to confine/isolate the mate/demate electrical arcs or sparks.
- e. Contact Orientation - All efforts shall be made to arrange contacts within connectors such that when the connectors are demated there will be no voltage potential on exposed male pins.

11.10.3.3 Structural Connectors Design Requirements

All IVA and EVA structural connectors shall meet the following requirements:

- a. Alignment Provisions - All structural connectors shall incorporate alignment features.
- b. Soft Latching - All structural connectors shall provide the capability to "soft-latch" prior to full firm connection or full release.
- c. Lock Indication - All structural connectors will provide an indication of positive locking.

11.10.3.4 Optical Connectors Design Requirements

All fiber optic connectors shall be designed so that proper geometric alignment and abutment maintains signal fidelity.

11.10.3.5 Connector Identification/Alignment Design Requirements

Connectors shall be selected, designed, and installed so they cannot be mated or cross-connected. The following requirements are applicable:

- a. Connector Shape - Use connectors that are clearly different and physically incompatible when lines differ in content (i.e., different voltages, liquids, gases).
- b. Alignment Provisions:
 - 1. Mating connectors shall be provided with aligning pins or equivalent devices to aid in alignment and to preclude inserting in other than the desired orientation.
 - 2. If aligning pins are used on Electrical connectors, they shall extend beyond the plug's electrical pins to ensure that alignment is obtained before the electrical pins engage.
- c. Keying
 - 1. Symmetrical arrangement of aligning pins or keys shall be avoided to prevent connectors from being mated.

2. The mechanical keys shall prevent incorrect connection with other accessible connectors, plugs, or receptacles.

d. Alignment marks:

1. Alignment marks shall be applied to mating parts if the proper interface orientation is not obvious by virtue of geometry.

2. The marks shall consist of a straight line of a width and length appropriate to the size of the items and shall be located so as to be easily seen by the crewmember both before and after mating/demating operations.

e. Coding:

1. Both halves of mating connectors shall display a code or identifier unique to that connection.

2. Labels or codes on connectors and associated items shall be located so they are visible when connected or disconnected.

f. Pin Identification - Each pin shall be clearly identified in each electrical plug and each electrical receptacle.

g. Orientation - Grouped plugs and receptacles shall be oriented so that the aligning pins or equivalent devices are in the same relative position (i.e., all keyed connectors oriented the same direction - key up).

h. Loose Hoses or Cables:

1. If the connectors on the ends of a loose electrical cable or fluid hose are not identical, each end shall be uniquely identified to prevent improper usage.

2. The loose ends of hoses and cables shall be restrained to prevent them from floating out of reach and to avoid injury to crewmembers and damage to equipment.

11.10.3.6 Connector Arrangement Design Requirements

All types of IVA and EVA connectors shall comply with the following arrangement and spacing requirements:

a. Hand Access - Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting.

b. Adjacent Connectors or Obstructions - Space between a connector and any adjacent obstruction shall be compatible with the size and shape of the plugs.

c. Single Rows - Connectors in a single row which require removal and replacement by the crew (IVA) shall be a minimum of 25 mm (1 in.) apart (edge-to-edge) for hand access during alignment and insertion. A separation of 41 mm (1.6 in.) is required for EVA and preferred for

IVA. (See Figure 11.10.3.6-1).

d. Staggered Rows - Staggered rows of connectors shall be a minimum of 64 mm (2.5 in) apart - IVA and EVA, (see Figure 11.10.3.6-2).

e. Tools - If a tool is used, the hand access clearance is still required to facilitate initial alignment by hand.

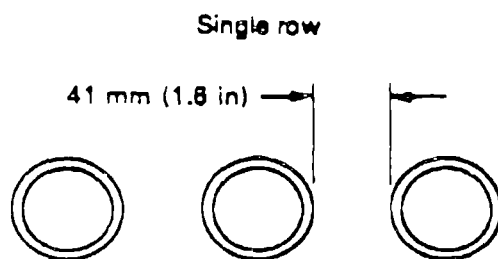
11.11 WINDOWS

11.11.1 Introduction - N/A

11.11.2 Window Design Considerations - N/A

11.11.3 Window Design Requirements

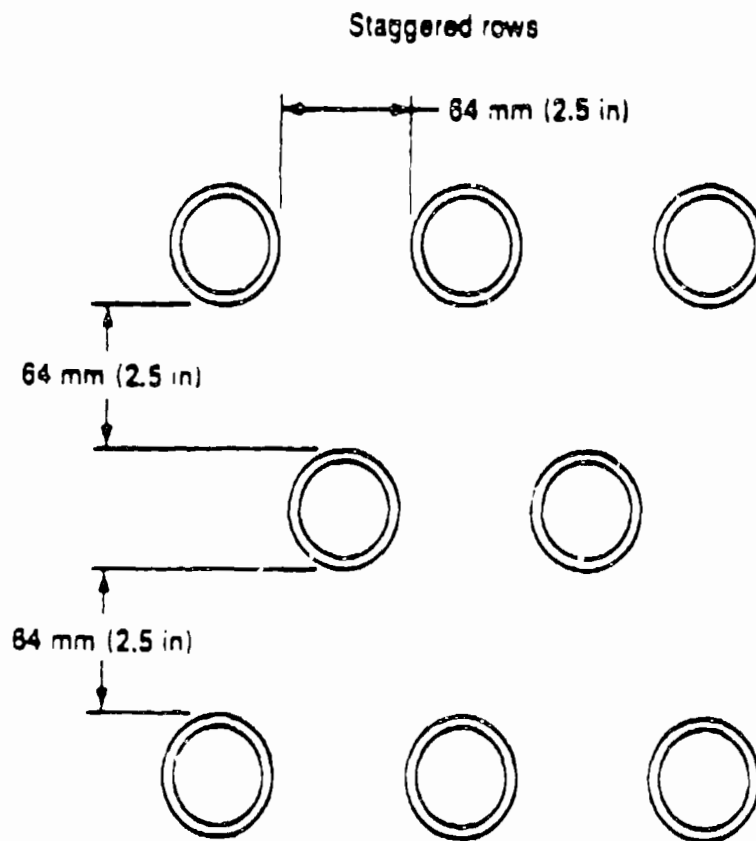
This section provides the design requirements for the optical characteristics, visual protection, and maintenance for windows to be utilized in the Assured Crew Return Vehicle. These requirements apply to test conditions prior to launch.



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Reference: 1, Figure 3.6-5, page 3.6-5

Figure 11.10.3.6-1 Preferred Spacing of Single Row of Connectors



Reference: 1, Figure 3.6-8, page 3.6-5

Figure 11.10.3.6-2 Preferred Spacing of Staggered Rows of Connectors

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11.11.3.1 General Viewing Window Requirements

11.11.3.1.1 Window Size

Hatch windows shall be a minimum of 20.3 cm (8 in) diameter. Other windows (if required) shall be sized appropriately to satisfy mission requirements.

11.11.3.1.2 Surface Reflections

- a. Windows shall be designed such that specular reflectance from each air-glass interface shall not exceed 1.5 percent for light incident on the surface.
- b. When anti-reflection coatings are applied to windows, they shall not cause resolution degradation exceeding .007 mr (1.5 arc seconds).

11.11.3.1.3 Optical Characteristics

At completion of manufacture, the window panes, with all accepted coatings shall meet the following optical requirements within the clear viewing area.

- a. Deviation at any point on the window panes shall not exceed 1.45 mr (5 arc minutes). Tempered window panes shall not exceed 2.9 mr (10 arc minutes).
- b. Distortion of all types of window materials shall not exceed a plane slope of 1:24.
- c. Haze of the uncoated window pane for all thickness shall not be greater than 2%.
- d. Warp and Bow - All glass window panes shall not exhibit warp or bow greater than 0.030 inch per linear foot of the glass.
- e. Surface Parallelism - The surface parallelism between multipanes of window systems shall not exceed 0.58 mr (2 arc minutes) from inner surface to outer surface of the complete assembly.

11.11.3.1.4 Optical Density

Each pane shall be manufactured so that when multipanes form a window group the following transmittance shall be met.

- a. Infrared - The optical density shall be greater than one for wavelengths between 850 and 1000 nanometers (less than 10%). For wavelengths greater than 1000 nanometers, the transmittance shall be less than 8%.
- b. Ultraviolet - The optical density shall be greater than three for wavelengths between 320 and 280 nanometers. The optical density shall be greater than four for wavelengths between 190 and 280 nanometers.
- c. Visible - In the region between 420 and 850 nanometers, the transmittance through a window composite shall not be less than 70%. The transmissivity shall not vary more than 25% for incident angles between the window surface and LOS's ranging from 30 to 60 degrees.

11.11.3.1.5 Surface Quality

The surface of each window pane shall be such that digs shall not exceed 0.122 cm (0.050 inches) diameter and scratches shall not exceed 0.0015 cm (0.0006 inch) deep. Chips shall not exceed 0.078 cm (0.032 inch) in surface penetration and 0.04 cm (0.016 inch) in thickness.

11.11.3.1.6 Bubbles, Seeds

The maximum number of open seeds per surface shall not exceed three and shall not exceed 0.1225 cm (0.050 inch) in diameter. Open seeds shall be spaced a minimum of two inches apart.

- a. Size and Density - Seeds and bubbles shall not exceed 0.2 cm (0.08 inch) in diameter or exceed a total number of 5 per cubic inch.
- b. Striae - Striae shall not exceed a diameter of 0.2 cm (0.080 inch) and are limited to no more than 2 per square inch.
- c. Inclusions - Inclusions shall not exceed 0.37 cm (0.15 inch) in diameter and more than 1 per cubic inch.

11.11.3.2 Scientific Window Design Requirements - N/A**11.11.3.3 Visual Protection Design Requirements**

The window design shall meet the following requirements:

- a. Sun Shields/Shades:
 - 1. Sun shields- All viewing windows shall be provided with crew-operated, opaque sun shields capable of restricting all sunlight from entering the habitable compartments.
 - 2. External sun shades repositioning - If external shades are designed to cast a shadow over a window, they shall be provided with a means to be remotely repositioned by the window user.
- b. Radiation Protection - The sun shade, whether internal or external, shall be capable of reflecting radiant energy away from the window assembly.

11.11.3.4 Physical Protection Design Requirements

Window design shall meet the following surface contamination and breakage requirements which are imposed to ensure that the windows can be used for the intended observation functions and that the ACRV pressure integrity is maintained:

- a. External Surface Contamination Protection - Window design shall take into account all sources of external contamination and shall provide means for cleaning or replacing when degradation exceeds optical transmissivity requirements.

b. **Between-Pane Contamination Protection** - Window design shall take into account all sources of contamination that can occur between the transparency panes and shall provide a means for preventing or minimizing optical degradation due to these contaminants.

c. **Internal Surface Contamination Protection** - Window design shall take into account all sources of internal surface contamination and provide means for preventing or minimizing optical degradation due to these contaminants.

1. **Antifogging** - All innermost panes shall be designed for antifog protection such that breath condensation does not occur from a mouth-to-pane distance of 10 cm (4 in.).

2. **Inner Pane Coatings** - The innermost pane shall have no coatings except for antireflective coatings.

d. **Impact Load Protection** - The window assembly shall be capable of withstanding a blunt object impact load of 550 N (125 lbf) from any angle of incidence.

11.11.3.5 Window Maintenance Design Requirements

The following window maintenance requirements are imposed to minimize the crew workload and prevent degradation of the optical qualities of the window. Where surface scratching, pitting, or staining cannot be prevented by other means, provide removable window protective surfaces.

11.12 PACKAGING

11.12.1 Introduction - N/A

11.12.2 Packaging Design Considerations - N/A

11.12.3 Packaging Design Requirements

All IVA and EVA packaging shall meet the following design requirements:

- a. **Compatible With Stowage** - All packaging form must conform to the stowage space available.

- b. **Compatible With Environments** - All packaging must be able to resist physical environment exposure to which it will be exposed during ground handling, ground and air transportation and launch, on-orbit and (if returnable) entry operations.

- c. **Compatible With Contents** - All packaging must be able to resist the physical characteristics of its contents for the maximum time duration for which the contents must be packaged.

- d. **Compatible With Trash Disposal System** - All non-reusable packaging must be compatible with the trash collection and disposal system.

- e. **Packaging Restraint** - Provide means for physically attaching or restraining the package at all locations where the package may have to be temporarily placed during use.

- f. Labeling - All packages shall be clearly labeled as to their contents.
- g. Inventory Control Compatibility - All packages shall be designed to incorporate the coding features required by the inventory control system.
- h. Ease of Use:
 - 1. All packaging shall be designed to be usable without extensive manipulation of the packaging materials.
 - 2. All packaging shall be designed to provide efficient and convenient means of opening and where necessary, closing/resealing the package.
- i. Sizing - All packages shall be sized to be optimally suited for ease of handling and rate of consumption.
- j. Hazards:
 - 1. Packaging that incorporates pull-tabs, lids, and other easy opening features shall be designed such that the crewmember will not be injured during normal use of the feature.
 - 2. Packaging materials shall not introduce contaminants into the atmosphere.
- k. Loose Packaging Materials - Loose, void-filling materials shall not be used within a package.
- l. Mobility Aids - Provide interfaces on the package for the attachment of equipment mobility aids if necessary for the application.

11.13 CREW PERSONAL EQUIPMENT

11.14 CABLE MANAGEMENT

11.14.1 Introduction - N/A

11.14.2 Cable Management Design Considerations - N/A

11.14.3 Cable Management Design Requirements

The following cable management design requirements shall apply:

- a. Routing - Cables shall be routed so that they:
 - 1. Cannot be pinched by doors, lids, or slides.
 - 2. Will not be used as a translation device in a microgravity environment.
 - 3. Will not be bent sharply when connected or disconnected.

4. Are accessible to the crewmember.
 5. Do not infringe into the operational envelope nor constitute a safety hazard (i.e., sagging, hooking, etc.).
- b. Cable Clamps - Long conductors, bundles, or cables, shall be secured by means of clamps unless they are contained in wiring ducts or cable retractors.
 - c. Identification - Cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate. All replaceable wires and cables shall be uniquely identified with distinct number or color codes in accordance with Paragraph 9.5.3, Labeling and Coding Design Requirements.
 - d. Location of Test or Other Cables - If it is essential that test, experiment, or other cables terminate on control or display panel junction boxes or a crewmember, the receptacles and cable routing shall be designed such that the cables will not interfere with controls, displays, or the crewmembers.
 - e. Coding - Cables containing individually insulated conductors with a common sheath shall be coded.
 - f. Protection - Guards or other protection shall be provided for easily damaged conductors such as waveguides, high-frequency cables, or insulated high-voltage cables.
 - g. Retention - The ends of cables which will be disconnected frequently shall have retention provisions.

12.0 DESIGN FOR MAINTAINABILITY

12.1 INTRODUCTION - N/A

12.2 DESIGN FOR MAINTAINABILITY DESIGN CONSIDERATIONS - N/A

12.3 DESIGN FOR MAINTAINABILITY DESIGN REQUIREMENTS

12.3.1 Equipment Design Requirements

All flight hardware and software shall be designed to facilitate on-orbit maintenance, check-out and shall be compatible with ground maintenance capabilities.

Equipment design shall minimize both maintenance complexity and time requirements for maintenance.

All equipment shall be compatible with the standard SSFP tool list. Maintenance skills required for ACRV shall be compatible with SSFP skills requirements.

Equipment design for maintenance shall consider IVA as the prime resource, maintenance by EVA shall be contingency only.

12.3.1.1 General Maintainability Design Requirements

General requirements to be followed when designing for maintainability are presented below.



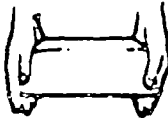
- a. Maintenance shall be considered only during attached operations.
- b. Independence - Systems and subsystems shall be as functionally, mechanically, electrically, and electronically independent as practical to facilitate maintenance.
- c. Maintenance Support Services - Maintenance support services (e.g., electrical outlets) shall be accessible at potential problem locations or at a designated maintenance location.
- d. Hazardous Conditions - System design shall preclude the introduction of hazardous conditions during maintenance procedures.
- e. Non-Critical Operations - Non-critical systems shall be designed to operate in degraded modes while awaiting maintenance. Degraded mode operation shall not cause additional damage to the system or aggravate the original fault.
- f. Redundancy Loss - Notification of loss of operational redundancy shall be provided immediately to the crew.
- g. Quick Release Fasteners - Quick release fasteners shall be used where consistent with other requirements (e.g., strength, sealing).

- h. Restraints - Personnel and equipment mobility aids and restraints shall be provided to support maintenance.
- i. Soldering, Welding, and Brazing - Soldering, welding, brazing, and similar operations during maintenance shall be considered.

12.3.1.2 Physical Accessibility Design Requirements

Design requirements for physical access to equipment for the purpose of maintainability are provided below.

- a. Relative Accessibility - Items most critical to system operation and which require rapid maintenance shall be most accessible. When relative criticality is not a factor, items requiring most frequent access shall be most accessible.
- b. Access Dimensions - The minimum sizes for access openings for two hands, one hand, and fingers are shown in Figure 12.3.1.2-1.
- c. Access - Access to inspect or replace an item (e.g., an ORU) shall not require removal of more than one access cover.
- d. Mounted Components - When feasible, components shall be no more than one deep in a bay or rack.
- e. Shape - Accesses shall be designed to the shape that will enable the crewmember to do his/her job and not be limited only to conventional shapes.
- f. Number of Accesses - Whenever possible, one large access shall be provided rather than a number of small ones.
- g. Protective Edges - Protective edges or fillets shall be provided on accesses that might injure crewmembers or their equipment.
- h. Damage Inspection and Repair - Where feasible, the design of structures and equipment, including their interfaces and all portions of the pressure shell, bulkheads, and seals shall be accessible for damage inspection and repair. This shall apply to exterior as well as to interior surfaces.
- i. Use of Tools and Test Equipment - Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.
- j. Service Points for Fluid Systems - Service points for filling, draining, and purging or bleeding shall be in accessible locations.
- k. Plug Connectors - Full access shall be provided to plug connectors.
- l. Cables :
 - 1. Cable access - Cables shall be routed so as to be readily accessible for inspection and repair.

Minimal two-hand access openings without visual access		
Reaching with both hands to depth of 150 mm (6.0 in) to 490 mm (19.28 in) Light clothing Width: 200 mm (8.0 in) or the depth of reach Height: 125 mm (5.0 in)		
Reaching full arm's length (to shoulders) with both arms (light clothing) Width: 500 mm (19.5 in) Height: 125 mm (5.0 in)		
Inserting box grasped by handles on the front: 13 mm (0.5 in) clearance around box, assuming adequate clearance around handles		
Inserting box with hands on the sides: Light clothing: Width: Box plus 115 mm (4.5 in) ‡ Height: 125 mm (5.0 in) or 13 mm (0.5 in) around box*		
* Whichever is larger ‡ If hands curl around bottom, allow an extra 38 mm (1.5 in.) for light clothing		
Minimal one-hand access openings without visual access		
	Height	Width
Empty hand, to wrist:		
Bare hand, rolled		85 mm (3.75 in) sq or dia
Bare hand, flat		55 mm (2.25 in) x 100 mm (4 in) or 100 mm (4 in) dia
Clenched hand, to wrist:		
Bare hand:		65 mm (3.75 in) x 125 mm (5.0 in) or 125 mm (5.0 in) dia
Arm to elbow:		
Light clothing:		100 mm (4.0 in) x 115 mm (4.5 in)
Arm to shoulder:		
Light clothing:		125 mm (5.0 in) sq or dia
Minimal finger-access to first joint		
Push button access:		
Bare hand:		32 mm dia (1.26 in)
Thermal gloved hand:		38 mm dia (1.5 in)
Two finger twist access:		
Bare hand:		object plus 80 mm (3.15 in)
Thermal gloved hand:		object plus 85 mm (3.35 in)

Reference: 2, Page 184

Figure 12.3.1.2-1 Minimum Sizes For Access Openings For Two Hands, One Hand, and Fingers

2. Cable trays - Wire harness and fluid lines mounted in cable trays shall be located for ready access.
3. Cable loops - Panel, console, and rack-mounted components shall have slack cable lengths or maintenance loops sufficient for removal of the connectors after the component has been extracted from its installed location, unless adequate internal access (physical and visual) is provided.
4. Cable Routing - Cables shall not be routed external to the face of the equipment rack.
- m. Fuses and Circuit Breakers - Fuses and circuit breakers shall be readily accessible for removal, replacement and resetting. The condition of fuses (good or blown) shall be readily discernable without having to remove the fuse.
- n. Structural Members - Structural components of units or chassis shall not prevent access to or removal of equipment.
- o. Fold-Out/Pull Out Drawers and Cabinets - Fold-Out/pull-out drawers and cabinets shall be used where possible to provide ease of access.
- p. Slide-Out Stops - Limit stops shall be provided on racks and drawers which are required to be pulled out of their installed positions for maintenance. The limit stop design shall permit convenient overriding of stops for unit removal.
- q. Hazardous Conditions - If a hazardous condition exists behind an access, a safety indicator shall be provided.
- r. Covers - Where physical access is required, one of the following practices shall be followed, with the order of preference as given.
 1. Provide a sliding or hinged cap or door where debris, moisture, or other foreign materials might otherwise create a problem.
 2. Provide a quick-opening cover plate in a cap that will meet stress requirements.
- s. Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position.
- t. Rear Access - Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate its full distance.

12.3.1.3 Visual Access Design Requirements

Requirements for visual access are provided below.

- a. Visual Access - Where visual access only is required, the following practices shall be followed with the order of preference as given.
 1. Provide an opening with no cover except where this might degrade system performance.

2. Provide a transparent window if dirt, moisture, or other foreign materials might create a problem.
 3. Provide a quick-opening metal cover if a transparent cover will not meet stress or other requirements.
- b. Visual and Manual Access - If the crewmember has to be able to see the task, design of the access shall be large enough to allow simultaneous visual as well as physical access; otherwise a separate window shall be provided for visual access to monitor task performance.
- c. Labeling:
1. Access labeling - Each equipment access shall be labeled to indicate items visible or accessible through it.
 2. Visibility - Relevant labels and mounting instructions shall be visible during all maintenance activities.
 3. Identification labels - Each access shall be labeled with a number, letter, or other symbol which is directly cross-referenced to the maintenance procedures.
 4. Plug configuration labels - When a plug-in device has to be inserted through a hole with limited visual access, a label adjacent to the access shall indicate how the pins on the device will align with the holes in the socket.
 5. Component identification labels - Electrical cables, fluid lines, and other subsystem protective shields shall be labeled or otherwise coded to allow for positive identification.
 6. Hazard labels - Accesses shall be labeled with appropriate hazard labels, advising of any hazard existing beyond the access and stating necessary precautions.
 7. Hinged cover labels - If instructions applying to a covered item are lettered on a hinged door, the lettering shall be oriented to be read by the crewmember performing maintenance when the door is opened.
- d. Fluid and Gas Line Connectors - Where feasible, fluid and gas connectors shall be located and configured so they can be inspected, and so that any leakage is obvious.

12.3.1.4 Removal, Replacement and Modularity Design Requirements

Design requirements for removal, replacement, and modularity are provided below.

- a. Removal - Systems and subsystems shall be designed so that failed Orbital Replacement Units (ORU's) can be removed without damaging or disturbing other components.
- b. Surface Removal - Replaceable units shall be designed for removal through the surface facing the crewmember as he works on the equipment.

- c. Independence - Where feasible, it shall not be necessary to remove or disable an operable unit to obtain access to a defective replaceable unit.
- d. Component Labeling - Each removable component and its position on the unit shall be labeled with corresponding numbers or other identification.
- e. Isolation Valves - Subsystems that contain liquids or high pressure gases (pressures exceeding 125 psia) and require maintenance shall be provided with isolation or disconnect valves to permit isolation and servicing and to aid in leak detection.
- f. Spillage control - Replaceable units shall be designed to control spillage and the release of gases during removal or replacement.
- g. Energized Units - Replaceable units and payloads which supply or receive energy shall be designed so that the power can be removed before repair, removal, or replacement is attempted. If stored energy can pose a hazard, provisions shall be made for its dissipation prior to maintenance.
- h. Fastener Coatings - Paint and/or coatings shall not adversely affect removal or installation of fasteners.
- i. Short Life Components - Easy replacement shall be provided for components that fail frequently (e.g., lamps and fuses).
- j. Guide Pins - For mounting and replacement of replaceable units, guides and guide pins shall be provided for alignment.
- k. Replacement Specificity - All replaceable items shall be designed so that it will be physically impossible to insert the unit incorrectly.
- l. Related Items - Items of the same or similar form which have different functional properties shall be readily identifiable and distinguishable, and shall not be physically interchangeable. This indication shall be readily discernable with the component in its installed position.
- m. Plug-In Installation - Plug-in type hardware installation and mounting techniques shall be employed.

12.3.2 Testability Design Requirements - N/A

12.3.2.1 Fault Detection and Isolation Design Requirements - N/A

12.3.2.2 Test Point Design Requirements

Design requirements for test points are provided below.

- a. Self-Checking - Appropriate test points shall be provided where a unit is not completely self-checking.
- b. Proximity - Test points shall be provided at or near maintenance locations.

- c. Adjustment - Test points used in adjusting a unit shall be in physical and visual proximity of the controls and displays used in the instrument.
- d. Labeling - Each test point shall be clearly labeled with a description of its function, or, at a minimum, with a code number keyed to the maintenance manual.
- e. Warning Labels - Test points shall be marked with appropriate warning labels when the application of conventional test probes could cause damage to internal circuits (e.g., integrated circuits) or injury to personnel.
- f. Troubleshooting - Sufficient test points shall be provided so that it will not be necessary to remove sub-assemblies to accomplish troubleshooting/fault diagnosis.
- g. Test Cable Termination - If it is essential that test cables terminate on control and display panels, the panel test receptacles shall be located so that the test cables will not interfere with controls and displays.
- h. Layout - Primary test points shall be grouped in a line or matrix that reflects the sequence of tests to be performed.
- i. Grouping - A control panel or a series of functionally autonomous panels shall be used to group test points whenever possible.
- j. Testing and Servicing - Rear plug connectors shall be accessible for testing and servicing except where precluded by potting, sealing, or other requirements.

13.0 FACILITY MANAGEMENT

13.1 INTRODUCTION - N/A

13.2 HOUSEKEEPING

13.2.1 Introduction - N/A

13.2.2 Housekeeping Design Considerations - N/A

13.2.3 Housekeeping Design Requirements

13.2.3.1 General Housekeeping Design Requirements

All systems shall be designed to minimize the need for housekeeping. The following general requirements shall be observed:

- a. Contamination Control During Ground Handling - The greatest practicable precautions shall be taken to ensure freedom from debris and surface contamination within the ACRV and individual systems and components during the ground operations from manufacture to launch.
- b. Surface Materials - Materials used for exposed interior surfaces shall be selected to minimize particulate and microbial contamination and be easy to clean (i.e., shall be smooth, solid, nonporous).
- c. Grids and Uneven Surfaces - Grids and uneven surfaces shall either not be used or they shall be easy to remove and easy to clean.
- d. Cracks and Crevices - All interior structural surfaces and equipment shall be free of narrow openings and crevices that can collect liquid or particulate matter or that require a special tool for cleaning.
- e. Closures - Closures shall be provided for any area that cannot be easily cleaned.

13.2.3.2 Surface Cleaning Design Requirements - N/A

13.2.3.3 Vacuum Cleaning Design Requirements - N/A

13.2.3.4 Air Filter Design Requirements

Filters used in the air revitalization system and air-cooled equipment collect airborne debris and, therefore, become an indirect but important element of the housekeeping system. Equipment filters shall be designed to provide the following housekeeping features:

- a. Access - Air filters (grids, screens, filter surfaces) shall be readily accessible for cleaning and replacement without disturbance of collected material.

b. Configuration - Nondisposable air filters shall be configured to allow them to be cleaned by a vacuum cleaner attachment.

c. Filter Condition - The design of the air filter shall incorporate the means to inform the crew of the overall condition of the filter (e.g., visual feedback, DELTA F sensor).

14.0 EXTRAVEHICULAR ACTIVITY (EVA)

14.1 GENERAL EVA INFORMATION

14.1.1 General EVA Information Introduction - N/A

14.1.2 General EVA Design Considerations - N/A

14.1.3 General EVA Safety Design Requirements

EVA crew safety shall be the paramount consideration in all EVA tasks. Though no planned EVA will occur during ACRV operational activities, during quiescent periods Space Station crewmembers may have EVA requirements on or around the ACRV (periodic maintenance, for example). Appropriate safety provisions must be designed into ACRV to account for this Space Station EVA on or around ACRV.

The following EVA safety requirements are a compilation of general design features that shall be included in systems to ensure the safety of the crew and space module equipment. The following safety requirements shall be followed to ensure the safety of the EVA crewmembers:

- a. Temperatures - Surface temperatures of space module components requiring EVA interface shall be compatible with the touch-temperature limits of the pressure suit design being used.
- b. Edges and Protrusions - All space module equipment and structures requiring an EVA interface must either be designed to preclude sharp edges or protrusions, or must be covered to protect the crewmember and the crewmember's critical support equipment.
- c. Hazardous Equipment - Potentially hazardous items that could injure EVA crewmembers or damage EVA equipment by entrapment, snagging, tearing, puncturing, cutting, burning, or abrading shall be designed to ensure elimination of, or protection from, the hazard.
- d. Transmitters - Procedures shall be developed to protect crewmembers during EVA approaches that may result in harmful exposures to the non-ionizing radiation being emitted from all high-power electromagnetic EM wave transmitters (microwave, radar, laser, radio, UV/IR visible lamps) on or in the space module with exterior antennas or external apertures.
- e. Tethers - EVA crewmembers shall be safety tethered to the space module at all times in microgravity, unless they are in a free-flying maneuvering unit or otherwise suitably restrained.
- f. Electrical Voltage - The EVA crewmember shall be protected against electric voltage shocks from inadvertent grounding of electric circuits and from electrical discharge resulting from static charge build-up.

14.2 EVA PHYSIOLOGY

14.2.1 Introduction - N/A

14.2.2 EVA Physiological Design Considerations - N/A

14.2.3 EVA Physiological Design Requirements

This section includes design requirements for the physiological aspects of EVA.

14.3 EVA ANTHROPOMETRY - N/A

14.4 EVA WORKSTATIONS AND RESTRAINTS

14.4.1 Introduction - N/A

14.4.2 EVA Workstation and Restraint Design Considerations - N/A

14.4.3 EVA Workstation and Restraint Design Requirements

14.4.3.1 EV Work Envelope Design Requirements - N/A

14.4.3.2 EVA Control and Display Design Requirements - N/A

14.4.3.3 EVA Workstation Lighting Design Requirements - N/A

14.4.3.4 EVA Crew Restraint Design Requirements

The use and design of EVA crew restraints shall conform to the following requirements:

a. Force Exertion - Foot restraints shall be used for actuation or operation of equipment which requires the crewmember to exert forces exceeding those given in Figure 14.4.3.4-1. EVA waist tether restraint system may be used when actuation or operation of equipment does not require forces and durations greater than those specified in Figure 14.4.3.4-1.

b. Foot Restraints - EVA foot restraints shall:

1. Be designed to permit easy insertion and removal of pressure suit boots by the crewmember.
2. Accommodate all boot sizes without adjustment during use.
3. Require a deliberate action for removal of a boot.
4. Provide a contingency method for removal of a jammed boot from a foot restraint.
5. Provide the capability to resist loads applied by the crewmember.

c. EVA Safety Tethers and Safety Hooks - Tethers and tether hooks shall:

1. Have a handle that will fit the gloved hand of a space-suited crewmember, allow the hook to be free for utilization, and have a minimum length of 9.5 cm (3.75 in.).
2. Have design features that indicate whether the latch lock is engaged or disengaged, and to indicate direction for engaging and disengaging the lock.
3. Safety tether attachment hooks shall be removed and attachable by one-handed operation and employ a redundant lock feature such as push-to-open buttons that must be operated to disengage or release a tether.
4. Provide a contingency method for removal of a snagged tether or release of a crewmember from a tether hook.

14.4.3.5 EVA Equipment Tether Design Requirements

EVA equipment tethers shall be design to the following requirements:

- a. One-Handed Operations - All EVA equipment tethers shall be designed such that tether attachment and removal methods permit one-handed operation using a pressure suit glove.
- b. Common Attachment Point - All equipment tethers shall use a common attachment method.

Linear force	Duration
4.4 N (1.0 lbf)	4.5 sec
22.2 N (5.0 lbf)	2.1 sec
44.5 N (10.0 lbf)	1.4 sec

Reference: 253, page 5-9

Notes:

The maximum distance through which forces may be applied is 61 cm (24 in.)

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*Figure 14.4.3.4-1 Maximum Forces and Duration
Capable of a Tethered but
Free-Floating EVA Crewmember*

c. Tether Attachment Points - All equipment items shall be provided a standardized tether hook receptacle which is an integral part of each item and is compatible with NASA equipment. This standardized receptacle shall also be provided on the interfacing surface to which the item is to be secured.

d. Tether Lock Status Indicator - The tether lock shall be designed in such a way that it will be easy to recognize when the hook is locked/unlocked in both day and night lighting conditions.

14.5 EVA MOBILITY AND TRANSLATION

14.5.1 Introduction - N/A

14.5.2 EVA Mobility and Translation Design Considerations - N/A

14.5.3 EVA Mobility and Translation Design Requirements

14.5.3.1 EVA Translation Route Design Requirements

EVA translation routes shall conform to the following requirements:

a. Equipment - All equipment located along EVA translation routes shall be designed to withstand repeated use as mobility aids, or the equipment shall be guarded or protected. There shall be no protrusions, corners, or sharp edges along EVA translation routes.

b. Translation and Mobility Aids :

1. Mobility aids shall be located at terminal points and direction change points on established crew translation paths.

2. Mobility aids shall be placed in all locations where equipment is not available as a substitute.

3. For EVA translation, mobility aids shall not be separated by more than 90 cm (36 in.). The preferred spacing is 60 cm (24 in.).

c. Handholds:

1. The orientation of translation and mobility handholds shall be such that the body position normally assumed to perform a task may be attained, and that normal body movement may be accommodated.

2. They shall also be oriented such that the plane formed by the handhold longitudinal axis and the cross-section major axis is approximately parallel with the body torso frontal plane.

d. Danger Warnings:

1. Translation and mobility handholds located within 30.5 cm (12 in.) of flight equipment shall be identified and color coded (regarding danger of injury to the crewmember due to equipment failure).

2. Equipment located along translation routes that could be damaged by a translating crewmember shall be identified and color coded.

e. Cross Section of the Translation Route - the dimension of the translation route (see Figure 14.5.3.1-1) shall not be smaller than the dimension required for the EVA crewmember to reverse direction (EMU height + clearance). The exceptions to this are:

1. Corridors where access is possible from either side and the length is no more than twice the length of the smallest EVA suited crewmember.
2. Corridors that have access from at least one end and are not longer than the shortest EVA suited crewmember.

f. Equipment Accessibility - Translation and mobility handholds shall be positioned such that crew-operated equipment and consoles are accessible and are not obstructed visually or physically by the handholds.

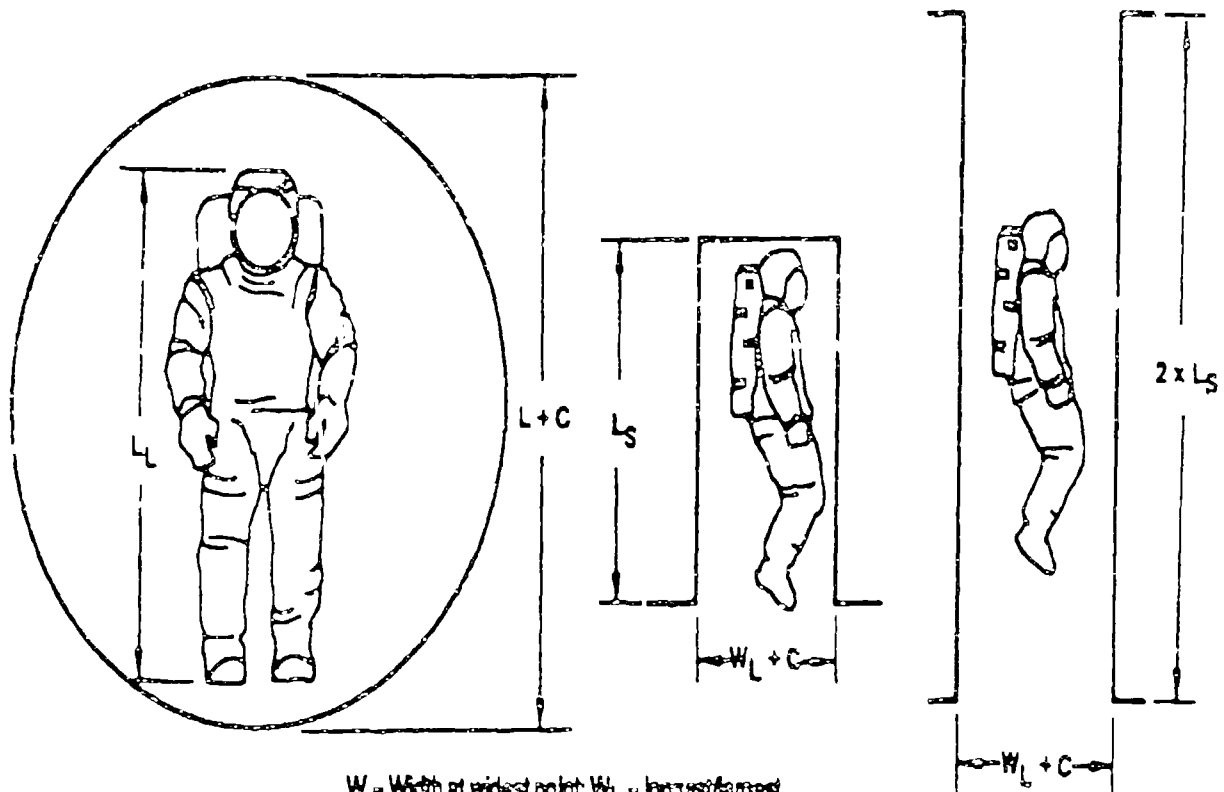
14.5.3.2 EVA Mobility Aids Design Requirements

EVA handholds/handrails shall conform to the following design requirements:

- a. Dimensions - EVA handhold and handrail dimensions shall conform to Figure 14.5.3.2-1.
- b. Mounting Clearance - The minimum clearance distance between the low surface of the handrail/handhold and the mounting surface is 5.7 cm (2.25 in.).
- c. Spacing for Translation - For EVA translation, handholds/handrails shall not be separated more than 92 cm (36 in.). Maximum spacing of 61 cm (24 in.) is preferred.
- d. Spacing for Worksites - Handrails/handholds shall not exceed 45.8 cm (18 in.) above or below the shoulder or 61 cm (24 in.) to the left or right of the body centerline when working in a foot-restraint position.
- e. Safety Tether Attachment - EVA handrails/handholds will accommodate safety tether hooks at a spacing not to exceed 90 cm (36 in) preferred 60 cm (24 in).
- f. Color - EVA handholds/handrails shall minimize specular reflection and shall be a standard color throughout the space modules, be clearly visible, and have a high visual contrast with the background.
- g. Temperature - Surface temperature of EVA handholds/handrails shall be compatible with the touch-temperature limits required by the space suit glove.

14.5.3.3 EVA Translation Restraints Design Requirements

Except for free flying maneuvering unit operation, EVA crewmembers in microgravity environments shall always be attached or otherwise restrained to the space module. Safety tether points shall be located as follows:



W = Width at widest point; W_L = longest/smallest

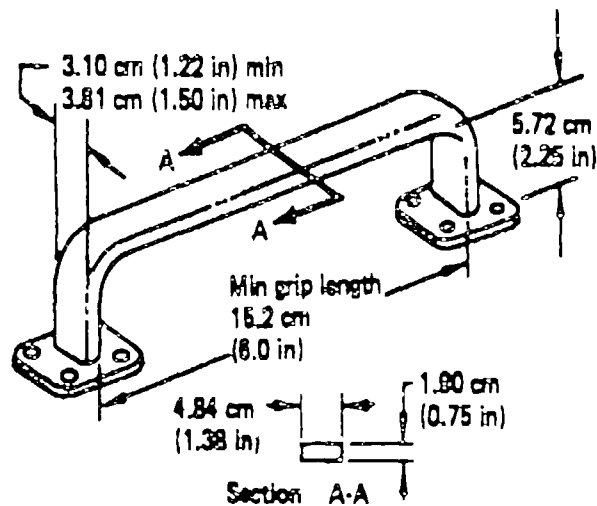
L = Length of EVA system; L_S = shortest/smallest; L_x = longest/smallest

C = Program specific clearance

Reference: 320,
351

Figure 14.5.3.1-1. Cross-Section of the EVA Translation Route

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Reference: 1, Figure 4.1-6, page 4.1-3
100, Table 11.2-1, page 80

Note: Dimensions +/- 0.15 cm (+/- 0.06 in)

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*Figure 14.5.3.2-1 Standard EVA Handhold
Dimensional Requirements*

- a. Translation Routes - No more than 90 cm (36 in.) between EVA translation aids, 60 cm (24 in.) preferred.
- b. Direction Change - At either side of a directional change in equipment transfer or a distinct hand-off point.
- c. Equipment Transfer Paths - At the extreme ends of equipment transfer paths.
- d. Tethers and Tether Hooks - Translation route tethers and tether hooks shall conform to the requirements in Paragraph 14.4.3.5, EVA Crew Restraint Design Requirements.